2013-1622

In The
United States Court Of Appeals
For The Federal Circuit

IN RE ANDERS WALLEN

Appeal from the United States Patent and Trademark Office, Patent Trial and Appeal Board in Serial No. 10/991,878

JOINT APPENDIX

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UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/991,878	11/18/2004	Anders Wallen	4015-5251	8906

24112 7590 03/11/2013

COATS & BENNETT, PLLC
1400 Crescent Green, Suite 300
Cary, NC 27518

EXAMINER	
YU, LIHONG	

ART UNIT	PAPER NUMBER
2631	

MAIL DATE	DELIVERY MODE
03/11/2013	PAPER

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

Ex parte ANDERS WALLEN

Appeal 2010-010555[1]
Application 10/991,878
Technology Center 2600

Before JEAN R. HOMERE, JOHNNY A. KUMAR and TREVOR M. JEFFERSON, *Administrative Patent Judges*.

HOMERE, *Administrative Patent Judge*.

DECISION ON APPEAL

---

[1] The real party in interest is Telefonaktiebolaget LM Ericsson. (App. Br. 2.)

I. STATEMENT OF THE CASE

Appellant appeals under 35 U.S.C. § 134(a) from the Examiner's Final Rejection of claims 1-35. (App. Br. 2.) We have jurisdiction under 35 U.S.C. § 6(b).

We affirm.

Appellant's Invention

Appellant invented a method and system for improving noise estimation processing in a wireless communication receiver. In particular, upon receiving a signal, a receiver circuit (12) generates an initial noise correlation estimate for which the receiver circuit calculates a corresponding error term as an error matrix. Then, the receiver circuit removes the error term from the noise correlation estimate to thereby obtain a compensated noise correlation estimate (matrix) therefor. (Fig. 1, [0012].)

Illustrative Claim

Independent claim 1 further illustrates the invention. It reads as follows:

> 1. A method of improving noise estimation processing in a wireless communication receiver comprising:
>
> generating a noise correlation estimate for a received signal;
>
> calculating an error term corresponding to the noise correlation estimate arising from a receiver frequency error; and
>
> obtaining a compensated noise correlation estimate by removing the error term from the noise correlation estimate.

Prior Art Relied Upon

Russell	US 4,477,912	Oct. 16, 1984
Ranganath	US 5,239,591	Aug. 24, 1993
Blakeney, II	US 5,490,165	Feb. 6, 1996
Kleinerman	US 6,470,047 B1	Oct. 22, 2002
Magee	US 6,563,885 B1	May 13, 2003
Wang	US 6,714,585 B1	Mar. 30, 2004
Mutoh	US 6,807,242 B1	Oct. 19, 2004
Bottomley	US 2005/0069023 A1	Mar. 31, 2005
Kim	US 7,408,894 B2	Aug. 5, 2008

Rejections on Appeal

The Examiner rejects the claims on appeal as follows:

a) Claims 1, 2, 5-8, 12-14, 16, 19, 23, 25, 26, and 29-31 are rejected under 35 U.S.C. § 103(a) as being unpatentable over Russell.

b) Claims 3 and 15 are rejected under 35 U.S.C. § 103(a) as being unpatentable over Russell and Kim.

c) Claims 4 and 18 are rejected under 35 U.S.C. § 103(a) as being unpatentable over Russell and Wang.

d) Clams 21 and 28 are rejected under 35 U.S.C. § 103(a) as being unpatentable over Russell and Bottomley.

e) Claims 9, 10, 22, 32, and 34 are rejected under 35 U.S.C. § 103(a) as being unpatentable over Russell and Magee.

f) Claim 11 is rejected under 35 U.S.C. § 103(a) as being unpatentable over Russell Magee, Kleinerman and Ranganath.

g) Claim 17 is rejected under 35 U.S.C. § 103(a) as being unpatentable over Russell and Blakeney.

h) Claim 20 is rejected under 35 U.S.C. § 103(a) as being unpatentable over Russell and Ranganath.

i) Claim 24 is rejected under 35 U.S.C. § 103(a) as being unpatentable over Russell and Mutoh.

j) Claim 27 is rejected under 35 U.S.C. § 103(a) as being unpatentable over Russell and Blakeney.

k) Claim 33 is rejected under 35 U.S.C. § 103(a) as being unpatentable over Russell, Magee, and Blakeney.

l) Claim 35 is rejected under 35 U.S.C. § 103(a) as being unpatentable over Russell, Magee, and Wang.

ANALYSIS

We consider Appellant's arguments *seriatim* as they are presented in the Appeal Brief, pages 9-25, and the Reply Brief, pages 3-9.

Dispositive Issue: Under 35 U.S.C. § 103, did the Examiner err in finding that Russell teaches or suggests *generating a noise correlation estimate for a received signal*, as recited in claim 1?

Appellant argues that Russell does not teach or suggest the disputed limitations emphasized above. (App. Br. 9-15, Reply Br. 3-8.) In particular, Appellant argues that while Russell discloses a correlation detection technique to recover a transmitted data sequence by correlating the received signal with a pseudo-random binary code used to spread the transmitted signal, such correlation detection pertains to code-division multiple access (CDMA), and not to a noise correlation estimate in a signal. (App. Br. 10, 13.) Therefore, the disclosed pseudo-random binary code is not noise signal. According to Appellant, even if the pseudo-random binary code were considered to be noise, Russell's disclosure would not be generating a noise correlation estimate because the correlation detector does not find an estimate for the pseudorandom code. Rather, the detector simply finds the best match between the incoming signal and a locally generated pseudo-random code, which is subsequently removed from the signal to recover the transmitted data. Thus, Russell at best discloses generating an estimate of the transmitted data sequence and not the pseudo-code. (App. Br. 14, Reply Br. 5.)

In response, the Examiner finds that Russell's disclosure of a correlation detector for estimating a pseudo-random binary code, which can include noise substantially, teaches the disputed limitations. (Ans. 4, 5, 17, and 18.)

Based upon our review of the record before us, we agree with the Examiner's underlying factual findings and ultimate conclusion of obviousness regarding claim 1. Russell discloses a correlation detection

circuit that uses a plurality of locally generated reference pseudorandom code words to decode a previously encoded signal including a stream of pseudorandom binary code words received from a data source. In particular, the correlation detector correlates the sequences in the encoded pseudorandom data stream successively with each of the reference pseudorandom code words to find a match therebetween. (Col. 9, ll. 3-11.) A feedback loop is subsequently used to eliminate frequency translation error resulting from the introduction of the pseudorandom codes in the signal. (Abstr.) We therefore find that because the received encoded signal includes a pseudorandom binary code that is successively compared with each locally generated reference pseudorandom sequence, Russell's estimation of the signal includes an estimation of the pseudorandom binary code contained therein. Further, we find that because the pseudorandom binary code contained in the signal can comprise of noise (Ans. 17-18, Reply Br. 6), Russell's disclosure of generating a correlation estimate for the pseudorandom binary code in the signal also teaches generating a noise correlation estimate.

Further, we find that Russell's disclosure of eliminating frequency translation error introduced by pseudorandom codes during the correlation from the transmitted signal teaches removing a calculated error term from the noise correlation estimate. We are therefore satisfied that the cited disclosures of Russell teach or suggest the disputed limitations. It follows that the Examiner did not err in rejecting claim 1 over Russell.

Regarding claims 2-35, Appellant reiterates substantially the same arguments submitted for the patentability of claim 1 above. (App. Br. 15-25.) As discussed above, these arguments are not persuasive. *See* 37 C.F.R. § 1.37(c)(1)(vii). Further, while Appellant raised additional arguments for patentability of the cited claims, we find that the Examiner has rebutted in the Answer each and every one of those arguments by a preponderance of the evidence. (Ans. 18-20.) Therefore, we adopt the Examiner's findings and underlying reasoning, which are incorporated herein by reference. Consequently, we have found no error in the Examiner's rejections of claims 2-35.

DECISION

We affirm the Examiner's obviousness rejections of claims 1-35 as set forth above.

No time period for taking any subsequent action in connection with this appeal may be extended under 37 C.F.R. § 1.136(a)(1)(iv).

AFFIRMED

ELD

Case: 13-1622 Document: 28 Page: 12 Filed: 01/22/2014

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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/991,878	11/18/2004	Anders Wallen	1009-0472 / P19605 US2	8906

102721 7590 05/29/2013

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EXAMINER	
YU, LIHONG	

ART UNIT	PAPER NUMBER
2631	

NOTIFICATION DATE	DELIVERY MODE
05/29/2013	ELECTRONIC

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official@mbhiplaw.com

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

Ex parte ANDERS WALLEN

Appeal 2010-010555[1]
Application 10/991,878
Technology Center 2600

Before JEAN R. HOMERE, JOHNNY A. KUMAR, and TREVOR M. JEFFERSON, *Administrative Patent Judges*.

HOMERE, *Administrative Patent Judge*.

DECISION ON REQUEST FOR REHEARING

STATEMENT OF THE CASE

In papers filed May 10, 2013, Appellant requests a rehearing under 37 C.F.R. § 41.52 from the Decision on Appeal ("Decision") of the Patent Trial and Appeal Board ("Board"), dated March 11, 2013. In the Decision, we affirmed the Examiner's rejection of claims 1-35. (Dec. 7.)

[1] The real party in interest is Telefonaktiebolaget LM Ericsson. (App. Br. 2.)

ANALYSIS

In the Request for Rehearing ("Request"), Appellant alleges that the Board erred by declining to discuss the merits Appellant's separate arguments regarding the patentability of claims 6 and 29, but instead chose to adopt the Examiner's findings to summarily affirm the rejection of those claims. In particular, Appellant argues that because they persuasively rebutted the Examiner's rejection of the cited claims by showing that the Examiner ignored the recited limitation of "generating an initial noise correlation matrix…based on propagation channel estimates," the Examiner did not establish by a preponderance of the evidence that the claims are unpatentable over Russell. (Req. Reh'g 2-6.)

We have carefully reviewed the Decision in light of Appellant's allegation of error. However, we find without merit Appellant's allegation that by not addressing the cited group of claims discussed by Appellant as a separate group with a separate heading, we did not consider Appellant's arguments. Appellant is reminded that merely placing an argument in a separate location with a separate heading from another argument does not necessarily make it a separate argument for patentability. It is the "substance" of such arguments that determines a separate argument for patentability. *See* 37 C.F.R. 41.37(c)(1)(vii). *See also In re Young*, 927 F.2d 588, 590 (Fed. Cir. 1991). During our deliberation, we thoroughly reviewed each of Appellant's arguments and weighed their merits against the findings proffered by Examiner in the Answer. After careful consideration of each group of claims argued in the Briefs, we found that the weight of the evidence favors the Examiner's rejection by a preponderance standard, and thereby decided to adopt the Examiner's findings.

For instance, regarding Appellant's allegation that the Examiner ignored the cited limitations of claims 6 and 29, the Examiner found that the Russell's disclosure of correlating "incoming pseudo binary code words with similar locally generated reference pseudo random binary code words" teaches the disputed limitations. (Ans. 5, 6.) Further, the Examiner found that because a matrix is a correlation of data items, a plurality of data values is a correlation matrix. (*Id*. at 19-20.) In our view, the cited findings by the Examiner address Appellant's contention that Russell does not teach a correlation matrix. (App. Br. 17-18.) Further, regarding Appellant's argument that Russell does not teach propagation channel estimates, we note the Examiner's unrebutted finding that Russell discloses a correlation matrix to generate noise estimates (Ans. 19, 20) can be equally applied to any transmission or reception media for the purpose of reducing noise therein. Therefore, it suffices that the disclosed correlation matrix be capable of performing the task of reducing noise in a channel or any other media in order for it to teach the disputed statement of intended use. Because we are satisfied that the Examiner has adequately established a *prima facie* case of obviousness against claims 6 and 29, which Appellant's arguments have not persuasively rebutted, we maintain our initial position to affirm the Examiner's rejection of claims 1-35 as set forth in the Decision.

DECISION

Accordingly, we have granted Appellant's Request to the extent that we have reconsidered the original Decision but have DENIED it with respect to making any changes to the Decision.

No time period for taking any subsequent action in connection with this appeal may be extended under 37 C.F.R. § 1.136(a)(1)(iv).

REHEARING DENIED

msc

UNITED STATES COURT OF APPEALS
FOR THE FEDERAL CIRCUIT

In re WALLEN)
Serial No. 10/991,878) **Appeal No: 2013-**

NOTICE FORWARDING CERTIFIED LIST

A notice of appeal to the United States Court of Appeals for the Federal Circuit was timely filed on July 22, 2013, in the Patent and Trademark Office in connection with the above-identified patent application. Pursuant to 35 U.S.C. § 143 and Federal Circuit Rule 17(b)(1), a certified list is this day being forwarded to the Federal Circuit.

Meredith H. Schoenfeld is the attorney representing the Director in this appeal. Counsel for appellants must contact the Solicitor's Office at 571-272-9035 to arrange for designating the record.

Respectfully submitted,

TERESA STANEK REA
Acting Under Secretary of Commerce for
Intellectual Property and Acting Director of the
United States Patent and Trademark Office

By: Kyra Abraham
Kyra Abraham
Paralegal
Mail Stop 8
P.O. Box 1450
Alexandria, VA 22313-1450
571-272-9035

Date: September 4, 2013

CERTIFICATE OF SERVICE

The undersigned hereby certifies that a true and correct copy of the above and foregoing has been served on counsel for Appellant this 4th day of September, 2013 as follows:

Daniel P. Homiller
Murphy Bilak & Homiller PLLC
8000 Regency Pkwy, Suite 415
Cary, NC 27518

By: Kyra Abraham

Kyra Abraham
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571-272-9035

Form PTO 55 (12-80)

U.S. DEPARTMENT OF COMMERCE
United States Patent and Trademark Office

September 4, 2013
(Date)

THIS IS TO CERTIFY that the annexed is a list of the contents comprised of the electronic file of the Patent Application identified below, said contents list being a list of the papers comprising the record before the United States Patent and Trademark Office for the Patent Application of:

Applicant(s): Anders Wallen

Date Filed: November 18, 2004

Serial No: 10/991,878

Title: METHOD AND APPARATUS TO COMPENSATE FOR RECEIVER FREQUENCY ERROR IN NOISE ESTIMATION PROCESSING

By authority of the

ACTING UNDERSECRETARY OF COMMERCE FOR INTELLECTUAL PROPERTY AND ACTING DIRECTOR OF THE UNITED STATES PATENT AND TRADEMARK OFFICE

Kyra Abraham

Certifying Officer

Date	Document
11/18/2004	PATENT APPLICATION
06/15/2005	INFORMATION DISCLOSURE STATEMENT
11/22/2005	STATUS REQUEST
02/19/2008	NON-FINAL OFFICE ACTION
05/19/2008	RESPONSE TO OFFICE ACTION
07/24/2008	FINAL REJECTION
09/24/2008	RESPONSE TO NON-FINAL OFFICE ACTION
10/10/2008	ADVISORY ACTION
10/20/2008	PRE-APPEAL BRIEF REQUEST FOR REVIEW
10/20/2008	NOTICE OF APPEAL
12/05/2008	NOTICE OF PANEL DECISION FROM PRE-APPEAL BRIEF REVIEW
02/04/2009	NON-FINAL OFFICE ACTION
05/04/2009	RESPONSE TO OFFICE ACTION
07/31/2009	NON-FINAL OFFICE ACTION
10/27/2009	PRE-APPEAL BRIEF REQUEST FOR REVIEW
10/27/2009	NOTICE OF APPEAL
01/13/2010	NOTICE OF PANEL DECISION FROM PRE-APPEAL BRIEF REVIEW
02/03/2010	APPEAL BRIEF
03/30/2010	EXAMINER'S ANSWER
05/28/2010	REPLY BRIEF
07/20/2010	NOTICE OF ENTRY OF REPLY BRIEF
08/05/2010	PTAB DOCKETING NOTICE
03/11/2013	DECISION ON APPEAL
03/19/2013	POWER OF ATTORNEY OR REVOCATION OF POWER OF ATTORNEY WITH A NEW POWER OF ATTORNEY AND CHANGE OF CORREAPONDENCE ADDRESS
03/27/2013	DENIAL OF REQUEST FOR POWER OF ATTORNEY
04/08/2013	POWER OF ATTORNEY OR REVOCATION OF POWER OF ATTORNEY WITH A NEW POWER OF ATTORNEY AND CHANGE OF CORREAPONDENCE ADDRESS
04/16/2013	NOTICE OF ACCEPTANCE OF POWER OF ATTORNEY
04/16/2013	NOTICE REGARDING CHANGE OF POWER OF ATTORNEY
05/10/2013	REQUEST FOR REHEARING
05/29/2013	DECISION ON REQUEST FOR REHEARING
07/03/2013	NOTICE OF ABANDONMENT
07/15/2013	NOTICE OF WITHDRAWAL OF ABANDONMENT
07/22/2013	APPEAL TO COURT OF APPEALS

18351 U.S. PTO
111804

PTO/SB/05 (09-04)
Approved for use through 07/31/2006. OMB 0651-0032
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UTILITY PATENT APPLICATION TRANSMITTAL

(Only for new nonprovisional applications under 37 CFR 1.53(b))

Attorney Docket No.	4015-5251
First Inventor	Anders Wallén
Title	Method and Apparatus to Compensate
Express Mail Label No.	EV 511669523 US

22141 U.S. PTO 10/991878 111804

APPLICATION ELEMENTS

See MPEP chapter 600 concerning utility patent application contents.

ADDRESS TO: **Commissioner for Patents P.O. Box 1450 Alexandria VA 22313-1450**

1. ☑ **Fee Transmittal Form** (e.g., PTO/SB/17) *(Submit an original and a duplicate for fee processing)*
2. ☐ **Applicant claims small entity status.** See 37 CFR 1.27.
3. ☑ **Specification** *[Total Pages* 23 *]* Both the claims and abstract must start on a new page *(For information on the preferred arrangement, see MPEP 608.01(a))*
4. ☑ **Drawing(s)** *(35 U.S.C. 113)* *[Total Sheets* 2 *]*
5. **Oath or Declaration** *[Total Sheets* 3 *]*
   - a. ☑ Newly executed (original or copy)
   - b. ☐ A copy from a prior application (37 CFR 1.63(d)) *(for continuation/divisional with Box 18 completed)*
     - i. ☐ DELETION OF INVENTOR(S) Signed statement attached deleting inventor(s) name in the prior application, see 37 CFR 1.63(d)(2) and 1.33(b).
6. ☐ **Application Data Sheet.** See 37 CFR 1.76
7. ☐ **CD-ROM or CD-R** in duplicate, large table or Computer Program *(Appendix)*
   ☐ Landscape Table on CD
8. **Nucleotide and/or Amino Acid Sequence Submission** *(if applicable, items a. – c. are required)*
   - a. ☐ Computer Readable Form (CRF)
   - b. Specification Sequence Listing on:
     - i. ☐ CD-ROM or CD-R (2 copies); or
     - ii. ☐ Paper
   - c. ☐ Statements verifying identity of above copies

ACCOMPANYING APPLICATION PARTS

9. ☑ **Assignment Papers** (cover sheet & document(s))
   Name of Assignee Telefonaktiebolaget L M Ericsson (publ)
10. ☐ **37 CFR 3.73(b) Statement** *(when there is an assignee)* ☑ **Power of Attorney**
11. ☐ **English Translation Document** *(if applicable)*
12. ☐ **Information Disclosure Statement** (PTO/SB/08 or PTO-1449)
    ☐ Copies of citations attached
13. ☐ **Preliminary Amendment**
14. ☑ **Return Receipt Postcard** (MPEP 503) *(Should be specifically itemized)*
15. ☐ **Certified Copy of Priority Document(s)** *(if foreign priority is claimed)*
16. ☐ **Nonpublication Request** under 35 U.S.C. 122(b)(2)(B)(i). Applicant must attach form PTO/SB/35 or equivalent.
17. ☑ Other: Express Mail Certification

18. If a CONTINUING APPLICATION, *check appropriate box, and supply the requisite information below and in the first sentence of the specification following the title, or in an Application Data Sheet under 37 CFR 1.76:*

☐ Continuation ☐ Divisional ☐ Continuation-in-part (CIP) of prior application No.: ....

Prior application information: *Examiner* ____________ *Art Unit:* ____________

19. CORRESPONDENCE ADDRESS

☑ The address associated with Customer Number: 24112 *OR* ☐ Correspondence address below

Name					
Address					
City		State		Zip Code	
Country		Telephone		Fax	

Signature	*[signature]*	Date	November 18, 2004
Name (Print/Type)	Michael D. Murphy	Registration No. (Attorney/Agent)	44,958

PTO/SB/17 (10-04v2)
Approved for use through 07/31/2006. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
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FEE TRANSMITTAL for FY 2005

Effective 10/01/2004. Patent fees are subject to annual revision.

☐ Applicant claims small entity status. See 37 CFR 1.27

TOTAL AMOUNT OF PAYMENT ($) 1,100.00

Complete if Known	
Application Number	TBA
Filing Date	TBA
First Named Inventor	Anders Wallén
Examiner Name	TBA
Art Unit	TBA
Attorney Docket No.	4015-5251

METHOD OF PAYMENT (*check all that apply*)

☑ Check ☐ Credit card ☐ Money Order ☐ Other ☐ None

☑ Deposit Account:

Deposit Account Number: 18-1167

Deposit Account Name:

The Director is authorized to: (*check all that apply*)

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☑ Charge any additional fee(s) or any underpayment of fee(s)

☐ Charge fee(s) indicated below, **except for the filing fee** to the above-identified deposit account.

FEE CALCULATION

1. BASIC FILING FEE

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description	Fee Paid
1001	790	2001	395	Utility filing fee	790.00
1002	350	2002	175	Design filing fee	
1003	550	2003	275	Plant filing fee	
1004	790	2004	395	Reissue filing fee	
1005	160	2005	80	Provisional filing fee	

SUBTOTAL (1) ($) 790.00

2. EXTRA CLAIM FEES FOR UTILITY AND REISSUE

			Extra Claims		Fee from below		Fee Paid
Total Claims	35	-20** =	15	X	18	=	270
Independent Claims	3	- 3** =	0	X		=	
Multiple Dependent						=	

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description
1202	18	2202	9	Claims in excess of 20
1201	88	2201	44	Independent claims in excess of 3
1203	300	2203	150	Multiple dependent claim, if not paid
1204	88	2204	44	** Reissue independent claims over original patent
1205	18	2205	9	** Reissue claims in excess of 20 and over original patent

SUBTOTAL (2) ($) 270.00

**or number previously paid, if greater; For Reissues, see above*

FEE CALCULATION (continued)

3. ADDITIONAL FEES

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description	Fee Paid
1051	130	2051	65	Surcharge - late filing fee or oath	
1052	50	2052	25	Surcharge - late provisional filing fee or cover sheet	
1053	130	1053	130	Non-English specification	
1812	2,520	1812	2,520	For filing a request for *ex parte* reexamination	
1804	920*	1804	920*	Requesting publication of SIR prior to Examiner action	
1805	1,840*	1805	1,840*	Requesting publication of SIR after Examiner action	
1251	110	2251	55	Extension for reply within first month	
1252	430	2252	215	Extension for reply within second month	
1253	980	2253	490	Extension for reply within third month	
1254	1,530	2254	765	Extension for reply within fourth month	
1255	2,080	2255	1,040	Extension for reply within fifth month	
1401	340	2401	170	Notice of Appeal	
1402	340	2402	170	Filing a brief in support of an appeal	
1403	300	2403	150	Request for oral hearing	
1451	1,510	1451	1,510	Petition to institute a public use proceeding	
1452	110	2452	55	Petition to revive - unavoidable	
1453	1,370	2453	685	Petition to revive - unintentional	
1501	1,370	2501	685	Utility issue fee (or reissue)	
1502	490	2502	245	Design issue fee	
1503	660	2503	330	Plant issue fee	
1460	130	1460	130	Petitions to the Commissioner	
1807	50	1807	50	Processing fee under 37 CFR 1.17(q)	
1806	180	1806	180	Submission of Information Disclosure Stmt	
8021	40	8021	40	Recording each patent assignment per property (times number of properties)	40.00
1809	790	2809	395	Filing a submission after final rejection (37 CFR 1.129(a))	
1810	790	2810	395	For each additional invention to be examined (37 CFR 1.129(b))	
1801	790	2801	395	Request for Continued Examination (RCE)	
1802	900	1802	900	Request for expedited examination of a design application	

Other fee (specify) ____________

*Reduced by Basic Filing Fee Paid

SUBTOTAL (3) ($) 40.00

SUBMITTED BY				(Complete *(if applicable)*)	
Name (Print/Type)	Michael D. Murphy	*Registration No. (Attorney/Agent)*	44,958	*Telephone*	919-854-1844
Signature	[signature]			*Date*	November 18, 2004

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of: **Anders Wallén.** Serial No.: TBA Filed: TBA Title: **METHOD AND APPARATUS TO COMPENSATE FOR RECEIVER FREQUENCY ERROR IN NOISE ESTIMATION PROCESSING**	**EXPRESS MAIL CERTIFICATION** **LABEL NO.: EV 511669523 US**

Attorney's Docket No: 4015-5251

Cary, North Carolina
November 18, 2004

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Respectfully submitted,

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UNITED STATES PATENT APPLICATION FOR GRANT OF LETTERS PATENT

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METHOD AND APPARATUS TO COMPENSATE FOR RECEIVER FREQUENCY ERROR IN NOISE ESTIMATION PROCESSING

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METHOD AND APPARATUS TO COMPENSATE FOR RECEIVER FREQUENCY ERROR IN NOISE ESTIMATION PROCESSING

RELATED APPLICATIONS

[0001] This application claims priority under 35 U.S.C. § 119(e) from the following U.S. provisional application: Application Serial No. 60/580,202, as filed on June 16, 2004. That application is expressly incorporated by reference herein.

BACKGROUND OF THE INVENTION

[0002] The present invention generally relates to wireless communication networks, and particularly relates to noise estimation processing in wireless communication receivers.

[0003] Noise estimation represents an integral part of receiver processing in wireless communication networks. For example, many types of modern wireless communication networks use "best-effort" packet data channels, where individual users are served at the highest data rates that can be supported given the prevailing radio and network conditions. Accurate noise estimation at the receivers is essential to the signal quality calculations performed at those receivers and, in turn, those signal quality calculations set the network's selection of serving data rates for the individual users.

[0004] If a wireless communication device operating on a best-effort channel reports an erroneously high received signal quality, the supporting network may select a serving data rate that is too high for reliable reception at the device. The built-in retransmission mechanisms, such as the use of Hybrid Automatic Repeat Requests (H-ARQ), commonly adopted for such best-effort channels exacerbate the problems associated with selecting serving data rate that is too high for reception conditions at the receiver, because the repeated retransmission of data packet erroneously received at the device lowers the effective data transmission rate. Indeed, with a high incidence of reception errors at the device, the effective data rate can be significantly lower than

would be achieved by selecting a lower data rate more commensurate with the actual received signal quality at the device.

[0005] Conversely, if the device reports an erroneously low received signal quality, the network selects a lower data rate than actually could be supported, and the best-effort channel is underutilized with respect to that device. The underutilization can be severe, depending upon the particular data rate setting method adopted by the network. In W-CDMA systems, mobile stations engaged in high-rate packet data services with the network, e.g., High Speed Downlink Packet Access (HSDPA) services, provide received signal quality feedback to the network in the form of transmitted Channel Quality Indicators (CQI).

[0006] Basically, the CQI reports from a given mobile station correspond to the signal-to-interference ratio (SIR) as measured by the mobile station for a reference channel signal transmitted from the network sector serving the mobile station. The CQI values reported by the mobile stations are "mapped" into a table of available data rates, and a mobile station that is under-reporting signal quality is thus allocated a lower data rate than its conditions can support.

[0007] Receiver frequency error represents a primary source of noise estimation errors. For example, accurate noise estimation at the receiver depends on accurately processing a received reference signal, e.g., received pilot symbols. Any error between the receiver's frequency and the (network) transmitter's frequency gives rise to symbol de-rotation errors, which in turn, cause noise and channel estimation errors at the receiver. Ideally, then, a wireless communication receiver would directly compensate its noise estimation processing based on observed receiver frequency errors.

SUMMARY OF THE INVENTION

[0008] The present invention comprises a method and apparatus for improved noise estimation in a wireless communication receiver. More particularly, the present invention provides for noise

estimation processing that incorporates an error term based on an estimate of receiver frequency error, which may be a relatively small residual frequency error remaining after Automatic Frequency Correction (AFC) processing at the receiver. Thus, a receiver configured according to one or more embodiments of the present invention generates an uncompensated noise estimate and a corresponding error term based on the observed (residual) frequency error of the receiver, and uses them to obtain a compensated noise estimate from which the frequency error bias is at least partially removed. That compensated (unbiased) noise estimate may then be used to improve any number of receiver functions, such as in the generation of signal quality measurements having improved accuracy, or in the generation of noise and interference suppression filters having improved suppression performance.

[0009] In one or more embodiments, the present invention comprises a method of improving noise estimation processing in a wireless communication receiver based on generating an estimate of noise correlation for a received signal, calculating an error term corresponding to the noise correlation estimate arising from a receiver frequency error, and obtaining a compensated noise correlation estimate by removing the error term from the noise correlation estimate. Note that with a zero mean assumption, the noise correlation estimate is expressed as a noise covariance estimate, and it should be understood that use of the term "noise covariance" herein does not exclude the more general notion of computing noise correlations where a non-zero mean is considered.

[0010] With that point in mind, a receiver may use received pilot symbols for noise covariance estimation, or it may use any other type of reference signal transmitted by a supporting wireless communication network to enable channel and noise estimation processing at the receiver. In a W-CDMA wireless communication network, for example, the receiver of interest may be comprised in a wireless communication device, and the included receiver circuit may use Common Pilot Channel (CPICH) symbols for channel and noise estimation processing.

[0011] Regardless of the particular reference signal used, the receiver may use noise correlation estimates that are compensated for receiver frequency error as the basis for calculating received signal quality estimates having an improved accuracy. That is, the receiver improves its calculation of signal quality estimates by wholly or partially removing the effects of receiver frequency error bias. These improved signal quality estimates may be transmitted to an associated wireless communication network in the form of CQI reports, or some other form of signal quality report, for use by the network in setting the data rates at which data is transmitted to the receiver.

[0012] According to one or more embodiments of the above method of improved noise estimation, a receiver circuit generates an initial noise correlation estimate as an uncompensated noise covariance matrix that is based on a received reference channel signal and corresponding propagation channel estimates. For example, the receiver circuit may generate propagation channel estimates and an uncompensated noise covariance matrix based on processing one or more received pilot symbols. In any case, the receiver circuit calculates the error term as an error matrix that is based on an estimate of the receiver frequency error and a channel correlation matrix determined from the propagation channel estimates, which may be expressed in terms of covariance. The receiver frequency error may be determined by estimating the phase shift that occurs over a given number of pilot symbols, or by some other means. Regardless of the particular processing carried out for receiver frequency error estimation, the resulting error matrix may be removed from the uncompensated noise covariance matrix to obtain a compensated noise covariance matrix that can then be used for signal quality estimation, filtering, etc.

[0013] In carrying out the above noise estimation processing, the receiver circuit can be configured as hardware, software, or any combination thereof. As such, the present invention may be embodied in one or more integrated circuits, such as Application Specific Integrated Circuits (ASICs) or Field Programmable Gate Arrays (FPGAs), or in electronic design files for synthesizing the appropriate processing logic in such devices, or as stored program instructions for execution by a microprocessor, Digital Signal Processor (DSP), or other digital logic processor. Further, the

receiver circuit may be implemented as part of, or in association with, additional receiver circuitry, including a RAKE-type receiver that provides one or more pilot channel despreaders (correlators) to obtain received pilot symbols and a channel estimation circuit to provide propagation channel estimates based on the despread pilot symbols.

[0014] Thus, in at least one embodiment of the receiver circuit, it includes a noise covariance estimation circuit configured to generate a noise covariance estimate for a received signal, and a compensation circuit configured to calculate an error term corresponding to the noise covariance estimate arising from a receiver frequency error and obtain a compensated noise covariance estimate by removing the error term from the noise covariance estimate. The receiver circuit may further include, or be associated with a signal quality estimation circuit configured to generate a signal quality estimate from the compensated noise covariance matrix, a frequency error estimation circuit configured to estimate the receiver frequency error used to calculate the error term, and with the aforementioned RAKE-type receiver and channel estimation circuits.

[0015] Of course, those skilled in the art will recognize that alternative circuit embodiments may be used, and that the above arrangement is given by way of non-limiting example. Indeed, the present invention is not limited by the above features and advantages, and those skilled in the art will recognize additional features and advantages upon reading the following detailed description, and upon viewing the accompanying figures.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] Fig. 1 is a block diagram of a wireless communication device in accordance with one or more embodiments of the present invention.

Fig. 2 is a block diagram of receiver details for the communication device of Fig. 1.

Fig. 3 is flow diagram of noise estimation processing logic in accordance with one or more embodiments of the present invention.

Fig. 4 is a flow diagram of processing logic details for one or more embodiments of the noise estimation processing outlined in Fig. 3.

DETAILED DESCRIPTION OF THE INVENTION

[0017] Fig. 1 illustrates a wireless communication device 10 that is configured in accordance with one or more embodiments of the present invention. Device 10 may comprise essentially any type of wireless communication device or system, and thus may comprise a mobile station, a Portable Digital Assistant (PDA), a pager, a laptop/palmtop computer, etc. In at least one embodiment, the wireless communication device 10 comprises a mobile station configured for operation in a cellular communication network. In at least one embodiment, the wireless communication device 10 comprises a mobile station configured for operation in a Wideband CDMA (W-CDMA) communication network.

[0018] Thus, with the understanding that device 10 is not limited by the disclosed illustrations, Fig. 1 depicts an arrangement wherein device 10 is adapted for wireless communication and comprises a receiver 12 to receive and process received signals, a transmitter 14 to generate and transmit signals, one or more antennas 16 coupled to receiver 12 and transmitter 14 via a switch/duplexer 18, a system controller 20 to support receive/transmit operations, and to support user interface (UI) 22, which may include a display, keypad, audio input/output transducers, etc.

[0019] Turning to receiver details for one or more embodiments of device 10, Fig. 2 partially illustrates the included receiver 12. In the illustrated embodiment, receiver 12 includes a radiofrequency (RF) front-end circuit 30, a RAKE-type receiver 32, a receiver circuit 34 that is configured for noise estimation processing in accordance with the present invention, and which may include, or be associated with, a signal quality estimation circuit 36, and an Automatic Frequency Control (AFC) circuit 38. In at least one embodiment of receiver circuit 34, which is of particular interest in the context of the present invention, it includes a noise covariance estimation circuit 40 configured to generate a noise estimate for the received signal, and a compensation circuit 42

configured to compensate the noise estimate for the receiver's frequency error. Such error generally is measured with respect to the transmitter frequency of the network transmitter originating the received signal.

[0020] The compensated noise estimate may be used by signal quality estimation circuit 36 to generate signal quality measurements having improved accuracy, i.e., having the receiver frequency error bias removed or at least reduced, and/or may be used to improve operation of RAKE receiver 32. For example, some embodiments of RAKE receiver 32 may incorporate the present invention's compensated noise correlation estimates into RAKE combining weight generation to provide improved interference and noise suppression. That is, a combining weight generator, whether included in receiver circuit 34, or RAKE receiver 32, may be configured to generate RAKE combining weights using the compensated noise correlation estimates, such that the combining weight generation is improved by reducing the effects on receiver frequency error.

[0021] RAKE receiver 32 can be associated with a receiver RF front-end circuit 30, which includes amplifiers, mixers, filters, and analog-to-digital converters (ADCs) as needed or desired. Front-end circuit 30 can be configured to provide the RAKE receiver 32 with one or more sampled signals r' (e.g., I/Q sample streams) corresponding to the received signal $r(t)$. Searcher 50 identifies one or more multipath components of the received signal arising from the time dispersive nature of multipath propagation, and delay estimator 52 generates corresponding delay estimates. In turn, pilot channel correlator(s) 54, channel estimator 56, and traffic correlator(s) 58, use those delay estimates to despread pilot and traffic symbols, and to make propagation channel estimates.

[0022] More particularly, in Direct Sequence CDMA embodiments of receiver 12, pilot channel correlator(s) 54 are time-aligned to one or more multipath rays of the received signal, and use a corresponding despreading code (e.g., Walsh code) to despread pilot symbols contained in the received signal, and channel estimator 56 uses the despread pilot symbols, which may be Common Pilot Channel (CPICH) symbols such as used in W-CDMA systems, to generate propagation channel estimates for the received signal. Those propagation channel estimates are used to

compensate the despread traffic channel symbols obtained from traffic correlators 58 for propagation channel phase and attenuation characteristics. RAKE combiner 60 generally improves the signal-to-noise ratio (SNR) of the received signal by combining the despread traffic symbols from each of one or more multipath rays of the received signal in RAKE combiner 60. The RAKE-combined signal output by combiner 60 is then provided to a decoder and/or other processing circuits in the receiver's signal processing chain.

[0023] In looking at noise estimation processing with respect to the receiver circuit 34, Fig. 3 illustrates processing details for one or more embodiments of the present invention, wherein receiver circuit 34 generates an initial noise correlation estimate for the received signal (Step 100). For zero mean, the noise correlation estimate is expressed as a noise covariance estimate. It should be understood that the present invention contemplates a configuration of receiver circuit 34 wherein its noise estimations generally are based on performing noise covariance calculations, but the more general noise correlation processing with non-zero may be implemented as needed or desired.

[0024] Regardless, processing continues with the calculation of an error term for the initial noise estimate, wherein the error term corresponds to a receiver frequency error (Step 102). In turn, the error term is used to obtain a compensated noise estimate (Step 104). More particularly, the initial uncompensated noise estimate, which is biased by receiver frequency error, is made into an unbiased estimate by compensating it for the receiver frequency error. In at least one embodiment of the present invention, the bias in the initial noise estimate arising from the receiver frequency error is removed to obtain an unbiased noise estimate by subtracting the error term from the initial (biased) noise estimate. It should be understood that such operations are based on scalar operations where the noise estimate is a scalar value, vector operations where the noise estimate is a vector value, and matrix operations where the noise estimate is a matrix value.

[0025] With the broad processing of Fig. 3 in mind, Fig. 4 illustrates noise estimation processing details for a given noise estimation interval. It should be understood that receiver 12

generally maintains updated noise estimations, which are used for periodically measuring and reporting signal quality to a supporting wireless communication network. In W-CDMA embodiments of device 10, the update interval is typically at least as short as 2 ms (500 Hz), which is the defined reporting interval for mobile station CQI reports that are returned to the network by devices engaged in high-rate packet data services on the HSDPA channel.

[0026] In support of noise estimation processing, receiver 12 receives and despreads pilot symbols (or any other type of suitable reference signal information), and generates propagation channel estimates from them (Steps 110 and 112). Let $y(k)$ be a vector of despread pilot signal samples from all fingers in a RAKE receiver during the kth symbol period:

$$y(k) = s(k)h(k)m(k) + n(k), \qquad (1)$$

where $s(k)$ denotes the kth transmitted reference symbol, $h(k)$ denotes the true channel response at time k, $m(k)$ is a multiplicative impairment, and $n(k)$ is additive noise. For simplicity, but without loss of generality, $s(k)$ can be set constant to "1" herein. When the receiver is subject to a residual frequency error, the multiplicative impairment can be expressed as

$$m(k) = e^{i2\pi\nu k}, \qquad (2)$$

where ν is a per reference symbol phase change corresponding to a residual receiver frequency error expressed as Δf. Note that with this method, the receiver frequency error can be determined over a defined duration of reference (pilot) symbols.

[0027] As for the per reference symbol phase change, it holds that

$$\nu = \Delta f \cdot T_{pilot}, \qquad (3)$$

where T_{pilot} is the duration of one reference symbol. In a W-CDMA embodiment, a CPICH reference symbol can be used, which would give T_{pilot} = 1/15000 s. By way of non-limiting example, receiver 12 may then be configured to generate channel estimates as,

$$\hat{h} = \frac{1}{N}\sum_{k=0}^{N-1} y(k), \qquad (4)$$

where $\hat{h}$ is the estimated channel response corresponding to the true channel response h, taken as an average over N reference symbols, e.g., CPICH symbols.

[0028] Using the channel estimates generated above, an estimate of the noise term at time k can be calculated as

$$\hat{n}(k) = y(k) - \hat{h}. \tag{5}$$

With the above noise formulation, receiver circuit 34 can be configured to calculate an initial noise covariance estimate (Step 114), $\hat{R}_0$, as

$$\hat{R}_0 = \frac{1}{N-1}\sum_{k=0}^{N-1}\hat{n}(k)\hat{n}^H(k). \tag{6}$$

[0029] The above noise estimate is an unbiased estimate in the absence of receiver frequency error, but includes a frequency-related bias error to the extent that the receiver's operating frequency mismatches the remote transmitter's frequency. AFC circuit 38 is configured to correct gross receiver frequency errors on an ongoing basis, but such corrections nonetheless leave non-zero residual frequency errors that contribute to noise estimation errors if not compensated for in noise estimation processing. As mentioned earlier herein, such errors can be significant because they cause device 10 to report a lower-than-actual received signal quality to a supporting wireless network, which causes the network to serve device 10 at a lower data rate than is appropriate for the actual received signal quality at device 10.

[0030] In the presence of receiver frequency error Δf, de-rotation of the reference symbols used in the channel and noise estimation processes suffer from error in proportion to the frequency error of receiver 12. In particular, the channel estimates generated in Eq. (4) can be expressed as

$$\hat{h} = \frac{1}{N}\sum_{k=0}^{N-1}y(k) = \frac{1}{N}\frac{1-e^{i2\pi\nu N}}{1-e^{i2\pi\nu}}\cdot h + \frac{1}{N}\sum_{k=0}^{N-1}n(k), \tag{7a}$$

and the estimate of the noise term in Eq. (5) can be expressed as

$$\hat{n}(k) = y(k) - \hat{h} = \left(e^{i2\pi\nu k} - \frac{1}{N}\frac{1-e^{i2\pi\nu N}}{1-e^{i2\pi\nu}} \right) \cdot h + n(k) - \frac{1}{N}\sum_{l=0}^{N-1} n(l). \qquad (7b)$$

With the above expressions in mind, an error term corresponding to receiver frequency error can be expressed as

$$\Delta R = \frac{1}{N-1}\left(N - \frac{1}{N}\frac{1-\cos(2\pi\nu N)}{1-\cos(2\pi\nu)} \right) hh^H, \qquad (8)$$

which can be implemented using the estimated channel response, i.e., using the propagation channel estimates $\hat{h}$, and thus expressed as,

$$\Delta R \approx \left(\frac{N(N+1)}{3}\pi^2\nu^2 \right)\hat{h}\hat{h}^H, \qquad (9)$$

where the first term in a Taylor series expansion has been used. Higher order terms also may be included, but they are negligible for moderate frequency errors. In error matrix form, the error term ΔR can be expressed as a function of the observed phase change ν, and the estimated channel covariance matrix given by $\hat{h}\hat{h}^H$. In the context of Fig. 4, then, processing continues with the calculation of the channel covariance matrix (Step 116) and the error matrix (Step 118).

[0031] In selecting values for the above equation in the context of W-CDMA embodiments of device 10, ν may be expressed as $\Delta f/15000$, where 15000 CPICH symbols are received per second, and where Δf is the residual receiver frequency error in Hz. Referring to Fig. 2, one sees that AFC circuit 38 may provide receiver circuit 34 with an indication of the residual frequency error as Δf, or pre-computed as ν. In either instance, the indication may be provided as a periodically updated digital value for use by compensation circuit 42.

[0032] Regardless of variations in the implementation details, the present invention compensates for receiver frequency errors in its noise estimation processing by directly considering the above equation. More particularly, the present invention obtains a compensated noise estimate by removing a frequency-related error term from its initial noise estimate. Set in the context

provided by the above equations, the receiver circuit 34 generates a noise covariance matrix $\hat{R}_0$ that includes a receiver frequency error bias, generates an error matrix ΔR that is proportional to that frequency error, and obtains a compensated noise covariance matrix $\hat{R}_{unbiased}$ based on removing the error matrix from the biased estimate. As such, the compensated estimate (in Step 120) may be obtained as,

$$\hat{R}_{unbiased} = \hat{R}_0 - \Delta R = \hat{R}_0 - \left(\frac{N(N+1)}{3}\pi^2 v^2\right)\hat{h}\hat{h}^H. \tag{10}$$

[0033] Thus, in at least one embodiment of the present invention, the compensated (unbiased) noise estimates are used for improved signal quality estimation, e.g., signal quality estimation circuitry uses the compensated noise estimates to calculate more accurate signal quality estimates (Step 122). Thus, the compensated noise covariance matrix, $\hat{R}_{unbiased}$, may be used by estimation circuit 36 to obtain an improved SIR estimate for the received signal, and thus to obtain an improved CQI value for reporting by device 10 to the supporting wireless network. Note that steps 110 through 122 thus may be carried out according to the desired SIR/CQI reporting interval. However, it should be understood that the present invention contemplates additional or alternative uses, such as the use of compensated noise estimates by RAKE receiver 32 to generate improved RAKE combining weights for noise suppression with respect to received traffic channel symbols.

[0034] In supporting signal quality reporting, AFC circuit 38 and/or compensation circuit 42 of receiver circuit 34 may periodically update the residual frequency error estimate, v (Steps 124 and 126), every N CPICH symbols, or may maintain a running average of v updated as CPICH symbols are received and despread. In either case, such processing may run concurrently with the noise estimation processing such that updated frequency error information is available as needed for compensating ongoing noise estimation processing.

[0035] With dynamically updated unbiased noise estimates thus available according to a defined update interval, one may take advantage of filtering to smooth the unbiased estimates, and thus obtain what, in some cases, may be a more suitable unbiased noise estimate. The desirability

of filtering the unbiased noise estimates and the degree of filtering applied may vary depending on the performance needs of device 10, and on the computational resources and demands attendant thereto. In any case, a filter may be implemented in receiver circuit 34 such that it outputs a filtered version of its unbiased noise estimates. This may be computed for example as,

$$\hat{R}_{filt} = \alpha\hat{R}_{filt} + (1-\alpha)\hat{R}_{unbiased}, \tag{11}$$

where α may be adjusted to control the filter response. For example, where $0 \le \alpha < 1$, then a setting close to 1 imposes heavier filtering and a setting at or close to 0 imposes lighter filtering.

[0036] In any case, SIR estimation in one or more embodiments of the present invention may be carried out by signal quality estimation circuit 36 according to,

$$\text{SINR} = \hat{\mathrm{h}}^H \hat{\mathrm{R}}^{-1}_{unbiased} \hat{\mathrm{h}}, \tag{12}$$

for a "Generalized" RAKE receiver embodiment that uses noise suppression/whitening in its RAKE combining weight generation. Where RAKE receiver 32 is configured for consideration of noise powers only, one may obtain a Signal-to-Noise-plus-Interference Ratio (SINR) by taking the diagonals of the unbiased noise covariance matrix thusly,

$$\text{SINR} = \sum_i \frac{|h(i)|^2}{\hat{r}_{unbiased}(i,i)}, \tag{13}$$

where $\hat{r}_{unbiased}(i,i)$ is the ith diagonal element of $\hat{R}_{unbiased}$. Finally, if RAKE receiver 32 does not incorporate noise statistics into its combining weight generation, then the SINR for the received signal is given as,

$$\text{SINR} = \frac{\mathbf{h}^H \mathbf{h}}{\sigma_I^2}, \tag{14}$$

where σ_I^2 can be computed as,

$$\sigma_I^2 = \frac{1}{J}\sum_{i=0}^{J-1} \hat{r}_{unbiased}(i,i), \tag{15}$$

where J denotes the total number of RAKE fingers.

[0037] With any of the above SINR computations, a corresponding CQI may be generated based on indexing a SINR-to-CQI lookup table, or based on making a SINR-to-CQI calculation. For more information, refer to the co-pending U.S. Application Serial No. 10/869,527, filed on 16 June 2004, and which is incorporated herein by reference. Note, too, that the filtered version of the unbiased noise estimates may be used in any of the above signal quality calculations.

[0038] Those skilled in the art should appreciate that the particular method(s) adopted for channel estimation, noise covariance estimation, signal quality estimation, and CQI reporting, if implemented, may be varied as needed or desired without departing from the scope of the present invention. Those skilled in the art will appreciate that should other methods be used, the expression for the covariance matrix error term may change correspondingly, but the methods disclosed herein remain valid with such changes. Indeed, the present invention is not limited by the foregoing discussion and accompanying illustrations, but rather is limited only by the following claims and their reasonable equivalents.

CLAIMS

What is claimed is:

1. A method of improving noise estimation processing in a wireless communication receiver comprising:

generating a noise correlation estimate for a received signal;

calculating an error term corresponding to the noise correlation estimate arising from a receiver frequency error; and

obtaining a compensated noise correlation estimate by removing the error term from the noise correlation estimate.

2. The method of claim 1, further comprising calculating a signal-to-interference ratio based on the compensated noise correlation estimate.

3. The method of claim 2, further comprising determining a Channel Quality Indicator from the signal-to-interference ratio for transmission to a supporting wireless communication network.

4. The method of claim 1, further comprising determining RAKE combining weights for a RAKE receiver circuit included in the wireless communication receiver based on the compensated noise correlation estimate.

5. The method of claim 1, further comprising determining signal quality estimates for the received signal based on the compensated noise correlation estimate.

6. The method of claim 1, wherein generating a noise correlation estimate for a received signal comprises generating an initial noise correlation matrix based on a received reference channel signal and corresponding propagation channel estimates.

7. The method of claim 6, wherein calculating an error term corresponding to the noise correlation estimate arising from a receiver frequency error comprises calculating an error matrix based on an estimate of the receiver frequency error and a channel correlation matrix determined from the propagation channel estimates.

8. The method of claim 7, wherein obtaining a compensated noise correlation estimate by removing the error term from the noise correlation estimate comprises subtracting the error matrix from the initial noise correlation matrix to obtain a compensated noise correlation matrix.

9. The method of claim 1, wherein generating a noise correlation estimate for a received signal comprises generating an initial noise covariance matrix based on a received reference channel signal and corresponding propagation channel estimates generated from the received reference channel signal.

10. The method of claim 9, wherein the reference channel signal is a pilot channel signal, and wherein the propagation channel estimates are generated from received pilot symbols.

11. The method of claim 10, wherein calculating an error term corresponding to the noise correlation estimate comprises calculating an error matrix based on determining an estimate of the receiver frequency error over a defined interval of pilot symbols, and wherein obtaining a compensated noise correlation estimate by removing the error term from the noise correlation estimate comprises subtracting the error matrix from the initial noise covariance matrix to obtain a compensated noise covariance matrix.

12. A wireless communication device comprising a receiver circuit configured to:

generate a noise correlation estimate for a received signal;

calculate an error term corresponding to the noise correlation estimate arising from a receiver frequency error; and

obtain a compensated noise correlation estimate by removing the error term from the noise correlation estimate.

13. The device of claim 12, wherein the receiver circuit includes a signal quality estimation circuit configured to estimate a signal quality for the received signal based on the compensated noise correlation estimate.

14. The device of claim 13, wherein the signal quality estimation circuit is configured to calculate a signal-to-interference ratio based on the compensated noise correlation estimate, such that the calculated signal-to-interference ratio is compensated for the receiver frequency error.

15. The device of claim 14, wherein the signal quality estimation circuit is configured to determine a Channel Quality Indicator value from the calculated signal-to-interference ratio, such that the Channel Quality Indictor value is compensated for the receiver frequency error.

16. The device of claim 12, wherein the receiver circuit includes or is associated with a frequency error estimation circuit configured to estimate the receiver frequency error used to calculate the error term.

17. The device of claim 16, wherein the frequency error estimation circuit is configured to estimate the receiver frequency error based on determining a symbol phase change over a defined interval of pilot symbols in a pilot signal received in association with the received signal.

18. The device of claim 12, further comprising a RAKE receiver operatively associated with the receiver circuit, said RAKE receiver configured to calculate RAKE combining weights based on the compensated noise correlation estimate, such that the RAKE combining weights are compensated for the receiver frequency error.

19. The device of claim 12, wherein the receiver circuit includes a noise correlation estimation circuit configured to generate the noise correlation estimate, and a compensation circuit configured to calculate the error term and to obtain the compensated noise correlation estimate.

20. The device of claim 19, wherein the noise correlation estimation circuit is configured to generate the noise correlation estimate as an initial noise covariance matrix, and wherein the compensation circuit is configured to calculate the error term as an error matrix based on the receiver frequency error, and to obtain the compensated noise correlation estimate as a compensated noise covariance matrix by subtracting the error matrix from the initial noise covariance matrix.

21. The device of claim 12, wherein the receiver circuit includes or is associated with a RAKE-type receiver configured to despread a received reference channel signal to obtain reference symbols, and a channel estimation circuit configured to generation propagation channel estimates from the reference symbols, and wherein the noise correlation estimate comprises a noise covariance matrix generated from the reference symbols and the corresponding propagation channel estimates.

22. The device of claim 12, wherein the receiver circuit is configured to generate the noise correlation estimate as a noise covariance matrix, and to obtain the compensated noise correlation

estimate as a compensated noise covariance matrix based on subtracting an error matrix from the noise correlation matrix, wherein the error matrix is based on the receiver frequency error.

23. The device of claim 12, wherein the device comprises a mobile station configured for operation in a cellular communication network, and wherein the mobile station is configured periodically to obtain compensated noise correlation estimates, and to generate and transmit Channel Quality Indicator reports to the cellular communication network based on the compensated noise correlation estimates.

24. The device of claim 12, wherein the device comprises a Wideband Code Division Multiple Access mobile station configured for operation in a Wideband Code Division Multiple Access wireless communication network.

25. A computer readable medium storing a computer program for a wireless communication device comprising:

program instructions to generate a noise correlation estimate for a received signal;

program instructions to calculate an error term corresponding to the noise correlation estimate arising from a receiver frequency error; and

program instructions to obtain a compensated noise correlation estimate by removing the error term from the noise correlation estimate.

26. The computer readable medium of claim 25, wherein the computer program comprises program instructions to generate a signal quality estimate from the compensated noise correlation estimate.

27. The computer readable medium of claim 26, wherein the computer program comprises program instructions to estimate the receiver frequency error used to calculate the error term based on observing symbol phase changes over a defined interval of reference channel symbols received in conjunction with the received signal.

28. The computer readable medium of claim 25, wherein the computer program comprises program instructions to generate propagation channel estimates based on despread reference symbols obtained from a received reference signal, and wherein the program instructions to generate the noise correlation estimate comprise program instructions to generate a noise correlation matrix from the reference symbols and the corresponding propagation channel estimates.

29. The computer readable medium of claim 25, wherein the program instructions to generate the noise correlation estimate comprises program instructions to generate a noise correlation matrix based on a received reference channel signal and corresponding propagation channel estimates.

30. The computer readable medium of claim 29, wherein the program instructions to calculate the error term comprise program instructions to calculate an error matrix based on an estimate of the receiver frequency error and a channel correlation matrix determined from the propagation channel estimates.

31. The computer readable medium of claim 30, wherein the program instructions to obtain the compensated noise correlation estimate comprise program instructions to obtain a compensated noise correlation matrix by subtracting the error matrix from the noise correlation matrix.

32. The computer readable medium of claim 25, wherein the program instructions to generate a noise correlation estimate for a received signal comprise program instructions to generate an initial noise covariance matrix having an error component arising from the receiver frequency error, and wherein the program instructions to obtain a compensated noise correlation estimate by removing the error term from the noise correlation estimate comprise program instructions to subtract an error matrix from the initial noise covariance matrix to obtain a compensated noise covariance matrix.

33. The computer readable medium of claim 32, wherein the program instructions to calculate an error term corresponding to the noise correlation estimate arising from a receiver frequency error comprises program instructions to compute an error matrix based on determining a pilot symbol phase change over a defined interval of pilot symbols received in association with the received signal.

34. The computer readable medium of claim 32, further comprising program instructions to compute a signal quality estimate for the received signal based on the compensated noise covariance matrix.

35. The computer readable medium of claim 32, further comprising program instructions to compute RAKE combining weights for RAKE receiver processing of the received signal based on the compensated noise covariance matrix.

ABSTRACT OF THE DISCLOSURE

A receiver circuit provides improved noise estimation processing by at least partially removing receiver frequency error bias. An initial noise estimate is compensated using an error term based on the observed receiver frequency error, and the resulting compensated noise estimate can be used to improve other signal processing in the receiver. For example, the receiver may use compensated noise estimates to generate signal quality estimates, e.g., Signal-to-Interference (SIR) estimates, having improved accuracy. Additionally, or alternatively, the receiver may use the compensated noise estimates to generate RAKE combining weights having improved noise suppression characteristics. In an exemplary embodiment, the initial noise estimate is a noise correlation matrix generated from a received reference signal, e.g., pilot symbols, and the error term is an error matrix directly generated using he observed receiver frequency error and channel estimates taken from the reference signal.

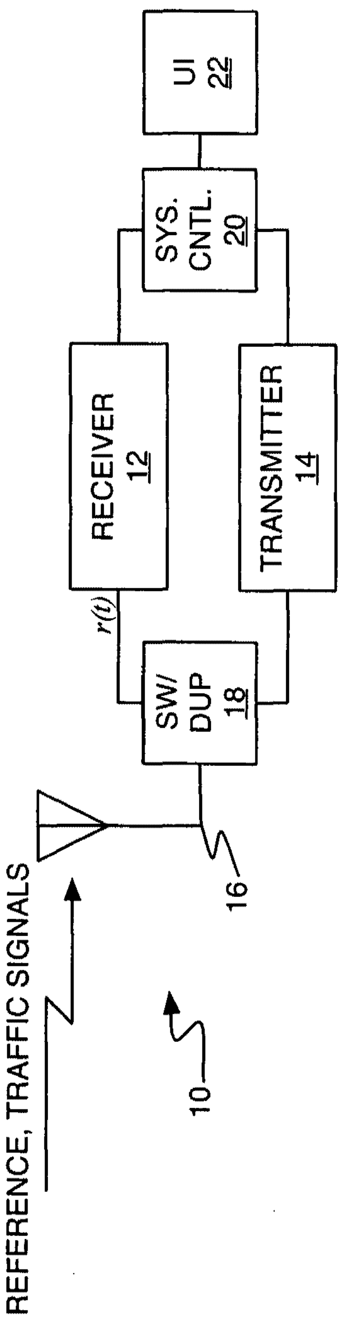
REFERENCE, TRAFFIC SIGNALS
10
16
SW/ DUP 18
r(t)
RECEIVER 12
TRANSMITTER 14
SYS. CNTL. 20
UI 22

FIG. 1

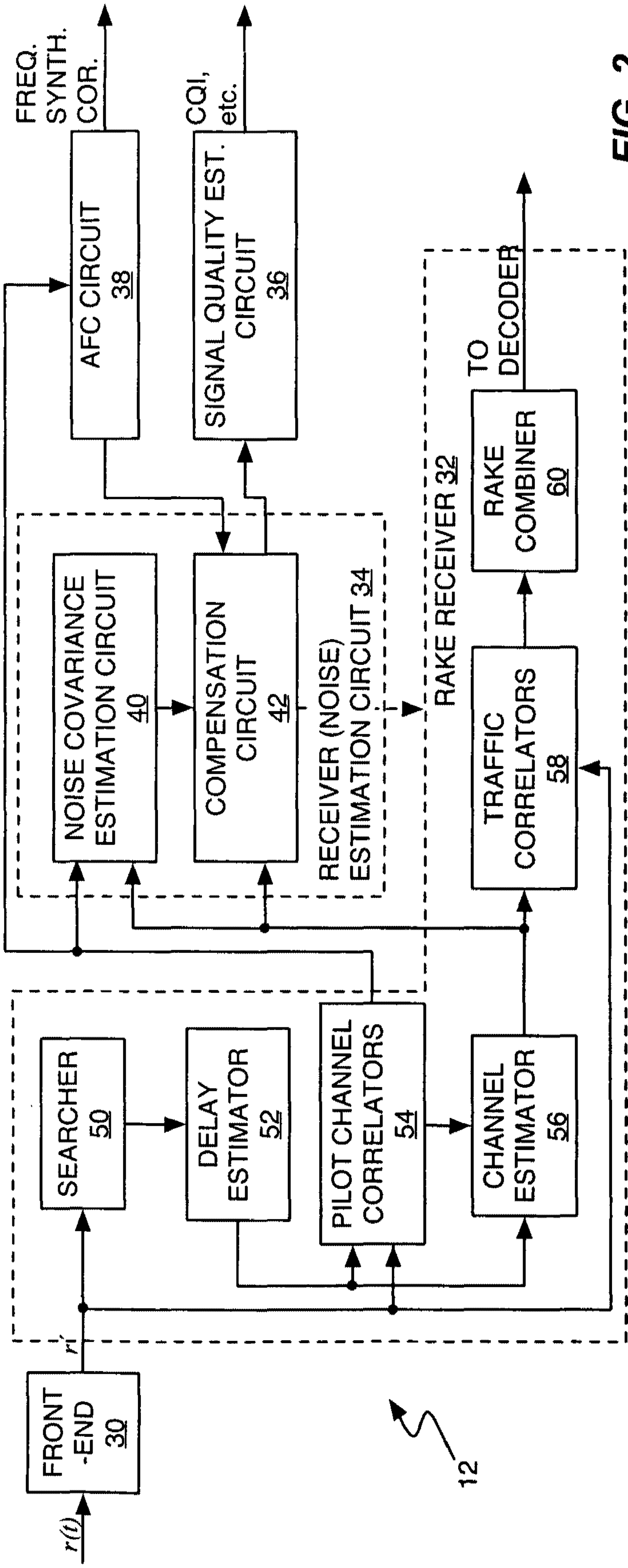
r(t)
FRONT -END 30
r'
SEARCHER 50
DELAY ESTIMATOR 52
PILOT CHANNEL CORRELATORS 54
CHANNEL ESTIMATOR 56
TRAFFIC CORRELATORS 58
RAKE COMBINER 60
TO DECODER
RAKE RECEIVER 32
NOISE COVARIANCE ESTIMATION CIRCUIT 40
COMPENSATION CIRCUIT 42
RECEIVER (NOISE) ESTIMATION CIRCUIT 34
AFC CIRCUIT 38
FREQ. SYNTH. COR.
SIGNAL QUALITY EST. CIRCUIT 36
CQI, etc.
12

FIG. 2

Case: 13-1622 Document: 25 Page: 48 Filed: 01/22/2014

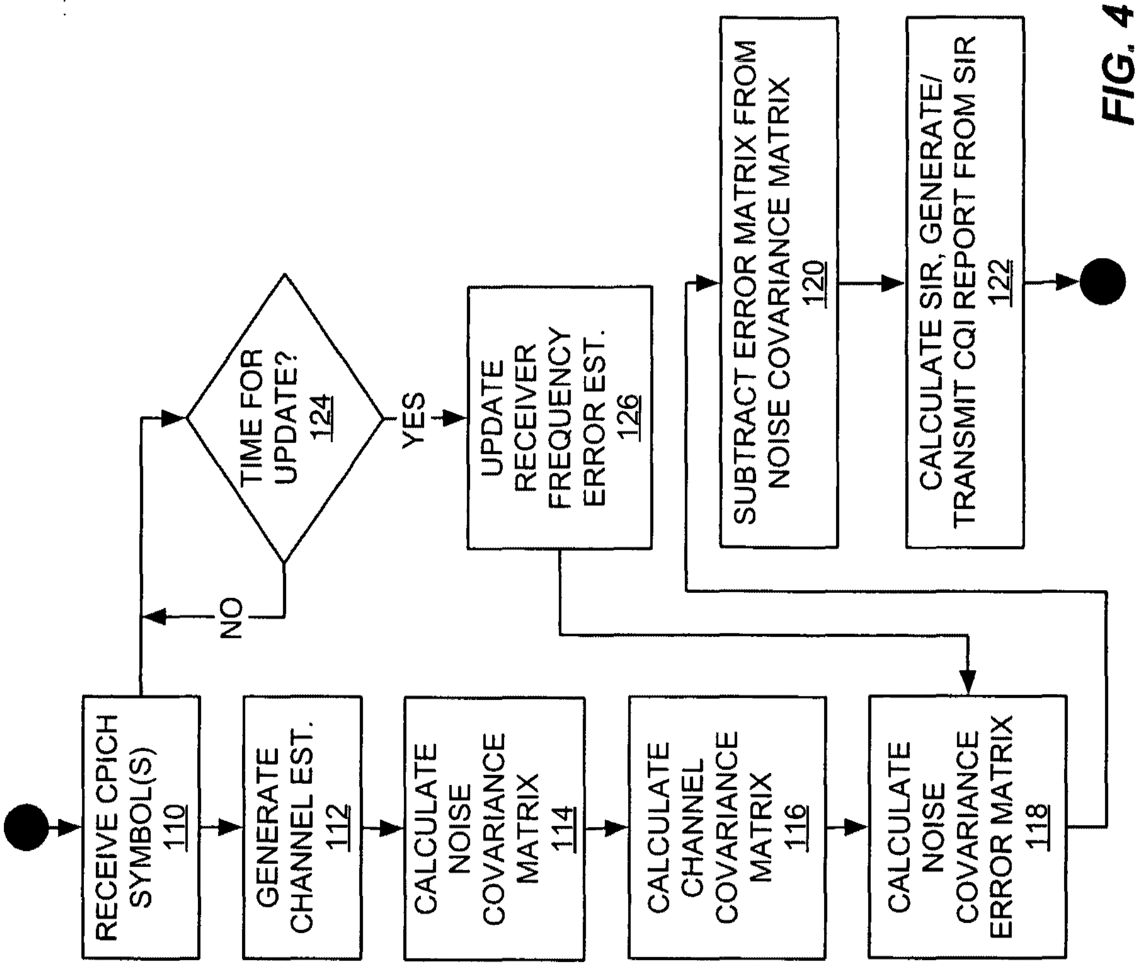

FIG. 4

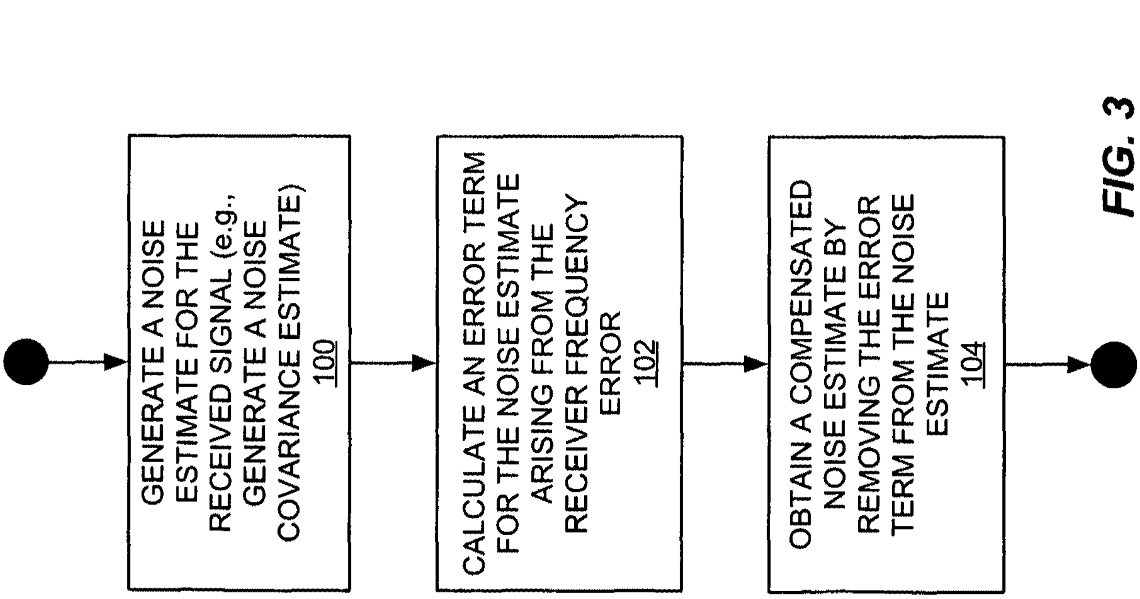

FIG. 3

Attorney Docket Number
4015-5251/P19605-US2-PUMP (Lund)

Declaration and Power of Attorney for Patent Application

As below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name,

I believe that I am the original, first and sole inventor of the subject matter which is claimed and for which a patent is sought on the invention entitled **METHOD AND APPARATUS TO COMPENSATE FOR RECEIVER FREQUENCY ERROR IN NOISE ESTIMATION PROCESSING** the specification of which

[X] is attached hereto.

(Check one)

[ ] was filed on ______________ as
Application Serial Number ______________
and was amended on ______________.
(if applicable)

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose to the U.S. Patent and Trademark Office all information known to me, which is material to patentability (as defined in C.F.R. §1.56) in connection with the examination of this application.

I hereby claim foreign benefits under Title 35, United States Code, §119 of any United States provisional applications, foreign application(s) for patent, or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

Prior Foreign Application(s)			Priority Claimed	
60/580,202 (Number)	USA (Country)	16 June 2004 (Day/Month/Year Filed)	[X] YES	[ ] NO
(Number)	(Country)	(Day/Month/Year Filed)	[ ] YES	[ ] NO
(Number)	(Country)	(Day/Month/Year Filed)	[ ] YES	[ ] NO

Attorney Docket Number
4015-5251/P19605-US2-PUMP (Lund)

Declaration and Power of Attorney for Patent Application

I hereby claim the benefit under Title 35, United States Code, §120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, §112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, §1.56(a) which occurred between the filing date of the prior application and the national or PCT international filing date of this application:

(Application Serial No.)	(Filing Date)	(Status: Patented/Pending/Abandoned)
(Application Serial No.)	(Filing Date)	(Status: Patented/Pending/Abandoned)

Power of Attorney: As a named inventor, I hereby appoint the following agents/attorneys to prosecute this application and transact all business in the Patent and Trademark Office connected therewith.

Mark C. Terrano
Registration Number 40,200

John Han
Registration Number 41,403

Sidney Weatherford
Registration Number 45,602

Roger Burleigh
Registration Number 40,542

And I also hereby appoint the Attorneys and Patent Agents of **Coats & Bennett, P.L.L.C.**, as identified by **Customer Number 24112** in the records of the United States Patent and Trademark Office and as updated from time to time, to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith.

24112

Attorney Docket Number
4015-5251/P19605-US2-PUMP (Lund)

Declaration and Power of Attorney for Patent Application

Send Correspondence to:	1400 Crescent Green, Suite 300 Cary, North Carolina 27511
Direct Calls to:	Michael D. Murphy (919) 854-1844

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

SOLE OR FIRST INVENTOR:

Full name: **Anders** **Wallén**
First Name — Middle Name/Initial — Last Name

Signature: ______ Date: 2004-11-17
First Name — Middle Name — Last Name — Year-Month-Day

Residence: **Eslöv, Sweden**
City, State, and Country

Citizenship: **Sweden**

Post Office Address: **Norregatan 45B, SE-241 33 Eslöv, Sweden**

PATENT APPLICATION FEE DETERMINATION RECORD
Effective October 1, 2004

Application or Docket Number
10 991878

CLAIMS AS FILED - PART I

	(Column 1)	(Column 2)
TOTAL CLAIMS	35	
FOR	NUMBER FILED	NUMBER EXTRA
TOTAL CHARGEABLE CLAIMS	35 minus 20=	* 15
INDEPENDENT CLAIMS	3 minus 3 =	* 0
MULTIPLE DEPENDENT CLAIM PRESENT		☐

* If the difference in column 1 is less than zero, enter "0" in column 2

SMALL ENTITY TYPE ☐ RATE	FEE	OR	OTHER THAN SMALL ENTITY RATE	FEE
BASIC FEE	395.00	OR	BASIC FEE	790.00
X$ 9=		OR	X$18=	270
X44=		OR	X88=	
+150=		OR	+300=	
TOTAL		OR	TOTAL	1060

CLAIMS AS AMENDED - PART II

AMENDMENT A

	(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA
Total	*	Minus	**	=
Independent	*	Minus	***	=
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM				☐

SMALL ENTITY RATE	ADDITIONAL FEE	OR	OTHER THAN SMALL ENTITY RATE	ADDITIONAL FEE
X$ 9=		OR	X$18=	
X44=		OR	X88=	
+150=		OR	+300=	
TOTAL ADDIT. FEE		OR	TOTAL ADDIT. FEE	

AMENDMENT B

	(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA
Total	*	Minus	**	=
Independent	*	Minus	***	=
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM				☐

RATE	ADDITIONAL FEE	OR	RATE	ADDITIONAL FEE
X$ 9=		OR	X$18=	
X44=		OR	X88=	
+150=		OR	+300=	
TOTAL ADDIT. FEE		OR	TOTAL ADDIT. FEE	

AMENDMENT C

	(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA
Total	*	Minus	**	=
Independent	*	Minus	***	=
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM				☐

RATE	ADDITIONAL FEE	OR	RATE	ADDITIONAL FEE
X$ 9=		OR	X$18=	
X44=		OR	X88=	
+150=		OR	+300=	
TOTAL ADDIT. FEE		OR	TOTAL ADDIT. FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20."
***If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3."
The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.

PATENT APPLICATION SERIAL NO. ____________________

U.S. DEPARTMENT OF COMMERCE
PATENT AND TRADEMARK OFFICE
FEE RECORD SHEET

11/22/2004 HLE333 00000062 10991878

01 FC:1001	790.00 OP
02 FC:1202	270.00 OP

PTO-1556
(5/87)

*U.S. Government Printing Office: 2002 — 489-267/69033

Case: 13-1622 Document: 25 Page: 54 Filed: 01/22/2014

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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/991,878	11/18/2004	Anders Wallen	4015-5251	8906

24112 7590 02/19/2008
COATS & BENNETT, PLLC
1400 Crescent Green, Suite 300
Cary, NC 27518

EXAMINER	
YU, LIHONG	

ART UNIT	PAPER NUMBER
4181	

MAIL DATE	DELIVERY MODE
02/19/2008	PAPER

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

PTOL-90A (Rev. 04/07)

Office Action Summary	Application No.	Applicant(s)	
	10/991,878	WALLEN, ANDERS	
	Examiner	**Art Unit**	
	LIHONG YU	4181	

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE _3_ MONTH(S) OR THIRTY (30) DAYS, WHICHEVER IS LONGER, FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

1)☒ Responsive to communication(s) filed on _11/18/2004_.

2a)☐ This action is **FINAL**. 2b)☒ This action is non-final.

3)☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims

4)☒ Claim(s) _1-35_ is/are pending in the application.

4a) Of the above claim(s) _____ is/are withdrawn from consideration.

5)☐ Claim(s) _____ is/are allowed.

6)☒ Claim(s) _1-35_ is/are rejected.

7)☐ Claim(s) _____ is/are objected to.

8)☐ Claim(s) _____ are subject to restriction and/or election requirement.

Application Papers

9)☐ The specification is objected to by the Examiner.

10)☒ The drawing(s) filed on _11/18/2004_ is/are: a)☒ accepted or b)☐ objected to by the Examiner.

Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).

Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

11)☐ The oath or declaration is objected to by the Examiner. Note the attached Office Action or form PTO-152.

Priority under 35 U.S.C. § 119

12)☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

a)☐ All b)☐ Some * c)☐ None of:

1.☐ Certified copies of the priority documents have been received.

2.☐ Certified copies of the priority documents have been received in Application No. _____.

3.☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

* See the attached detailed Office action for a list of the certified copies not received.

Attachment(s)

1) ☒ Notice of References Cited (PTO-892)
2) ☐ Notice of Draftsperson's Patent Drawing Review (PTO-948)
3) ☒ Information Disclosure Statement(s) (PTO/SB/08) Paper No(s)/Mail Date _06/15/2005_.
4) ☐ Interview Summary (PTO-413) Paper No(s)/Mail Date. _____ .
5) ☐ Notice of Informal Patent Application
6) ☐ Other: _____.

DETAILED ACTION

Claim Rejections - 35 USC § 112

1. The following is a quotation of the first paragraph of 35 U.S.C. 112:

> The specification shall contain a written description of the invention, and of the manner and process of making and using it, in such full, clear, concise, and exact terms as to enable any person skilled in the art to which it pertains, or with which it is most nearly connected, to make and use the same and shall set forth the best mode contemplated by the inventor of carrying out his invention.

2. Claim 12 is rejected under 35 U.S.C. 112, first paragraph, as failing to comply with the enablement requirement. Claim 12 is a single means claim which covered every conceivable means for achieving the stated purpose.

Claim Rejections - 35 USC § 103

1. The following is a quotation of 35 U.S.C. 103(a) which forms the basis for all obviousness rejections set forth in this Office action:

> (a) A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negatived by the manner in which the invention was made.

1. Claim 1, 2, 3, 5-17, 19, 20, 22-27, 29-34 are rejected under 35 U.S.C. 103(a) as being unpatentable over Kleinerman et al (US 6470047 B1) in view of Magee et al (US 6563885 B1).

Consider claims 1, 12 and 25, Kleinerman discloses a method of improving noise estimation processing in a wireless communication receiver (*see abstract and col. 1, lines 16-60, where Kleinerman is discussing a better noise prediction in a wireless communications*

receiver). Kleinerman discloses generating a noise correlation estimate (*see Fig. 3*) for a received signal (*see col. 14, lines 14- 54, col. 16, lines 55-64, and col. 13, lines 12-26, where Kleinerman teaches channel estimation using correlation method for calculating a noise vector, therefore a noise correlation estimate*). Kleinerman discloses calculating an error term corresponding to the noise correlation estimate arising from a receiver error (*see col. 15, lines 12-65, and col. 17, lines 1-28, where Kleinerman discloses comparing the noise vector, thus the noise correlation estimate, with previously generated interference templates*). Kleinerman discloses obtaining a compensated noise correlation estimate by removing the error term from the noise correlation estimate (*see col. 5, lines 35-67, where Kleinerman teaches a new channel estimate is calculated after compensation filtering; see col. 18, lines 8-58, where Kleinerman describes determining the coefficients for the compensation filter based on the interference template and the noise vector; see col. 19, lines 12-18, where Kleinerman teaches the compensation filter is operative to filter the received signal, therefore removing the error term*).

Kleinerman does not specifically disclose the receiver frequency error. Magee teaches receiver frequency error (*see col. 9, lines 64-67 and col. 10, lines 1-14, where Magee discusses noise estimator to compensate for phase lead or phase lag that can occur as a result of interference, therefore receiver frequency error*) .

It would have been obvious to one of ordinary skill in the art at the time the invention was made to modify the invention of Kleinerman, and have receiver frequency error included in noise estimation, as taught by Magee, thus allowing the phase contribution in the interference be removed, as discussed by Magee (*see col. 9, lines 45-63*).

Consider claims 2, 13, 26, Kleinerman discloses calculating a signal-to-interference ratio based on the compensated noise correlation estimate (*see col. 5, lines 19-35, where Kleinerman teaches maximizing the signal to interference ratio using channel estimation and compensation*).

Consider claims 3 and 15, Kleinerman discloses determining a Channel Quality Indicator from the signal-to-interference ratio for transmission to a supporting wireless communication network (*see col. 12, lines 1-11, col. 13, lines 38-54, and col. 19, lines 18-31, where Kleinerman discusses an interference detector for improving the signal to interference ratio, therefore a channel quality indicator*).

Consider claims 5, 14 and 34, Kleinerman discloses determining signal quality estimates for the received signal based on the compensated noise correlation estimate (*see col. 5, lines 19-35, where Kleinerman teaches maximizing the signal to interference ratio, therefore signal quality, using channel estimation and compensation*).

Consider claims 6 and 29, Kleinerman discloses generating an initial noise correlation matrix based on a received reference channel signal and corresponding propagation channel estimates (*see col. 5, lines 35-50, and col. 20, lines 14-42, where Kleinerman is discussing an invention is operative to first find the channel estimate and noise vector, therefore an initial noise correlation matrix, from the receive signal*).

Consider claims 7 and 30, Kleinerman discloses calculating an error term corresponding to the noise correlation estimate arising from a receiver frequency error comprises calculating an error matrix based on an estimate of the receiver frequency error and a channel correlation matrix determined from the propagation channel estimates (*see col. 19, lines 54-67, and col. 20, lines 1-61, where Kleinerman is discussing an error matrix in the noise vector estimation*).

Consider claims 8, 19 and 31, Kleinerman discloses obtaining a compensated noise correlation estimate by removing the error term from the noise correlation estimate comprises subtracting the error matrix from the initial noise correlation matrix to obtain a compensated noise correlation matrix (*see col. 5, lines 35-67, where Kleinerman teaches a new channel estimate and noise vector is calculated after compensation filtering, therefore a compensated noise correlation matrix*).

Consider claims 9, 20, 22 and 32, Kleinerman in view of Magee discloses the method of claim 1. Magee discloses generating an initial noise covariance matrix based on a received reference channel signal and corresponding propagation channel estimates generated from the received reference channel signal (*see col. 8, lines 42-65, where Magee discusses computation performed on the initial noise estimates for each of the antenna signals, thus received reference channel signal, to provide a covariance matrix; see col. 12, lines 22-65 and col. 19, lines 1-30, where Magee teaches updating the initial noise covariance matrix*).

Consider claim 10, 17 and 33, Kleinerman in view of Magee discloses the method of generating a noise estimate for a received signal. Magee discloses the reference channel signal is a pilot channel signal (*see col. 7, lines 12-64, where Magee is discussing a channel estimator configured to provide an indication of the magnitude and phase of the training tone (or pilot tone) of the data signals received at the antennas*), and wherein the propagation channel estimates are generated from received pilot symbols (*see col. 4, lines 1-37, where Magee is discussing computing a channel estimate using training tones for use in mitigating the effects of the interference caused by transmission of the received signal*).

Consider claims 11 and 27, the combination of Kleinerman and Magee disclose calculating an error term corresponding to the noise correlation estimate.
Kleinerman further discloses calculating an error matrix based on determining an estimate of the receiver frequency error over a defined interval of pilot symbols (*see col. 19, lines 54-67, and col. 20, lines 1-61, where Kleinerman is discussing an error matrix in the noise vector estimation; see col. 11, lines 15-23, where Kleinerman describes the channel estimate is obtained using a know training symbol sequence, therefore a defined interval of pilot symbols*), and wherein obtaining a compensated noise correlation estimate by removing the error term from the noise correlation estimate comprises subtracting the error matrix from the initial noise covariance matrix to obtain a compensated noise covariance matrix (*see col. 5, lines 35-67, where Kleinerman teaches a new channel estimate and noise vector is calculated after compensation filtering, therefore a compensated noise correlation matrix*).

Consider claim 16, the combination of Kleinerman and Magee disclose the device of claim 12. Kleinerman discloses the receiver circuit includes or is associated with an error estimation circuit configured to estimate the receiver error used to calculate the error term (*see col. 15, lines 12-65, and col. 17, lines 1-28, where Kleinerman discloses comparing the noise vector with previously generated interference templates, therefore an error estimation circuit*). Kleinerman does not specifically disclose the receiver frequency error. Magee teaches receiver frequency error (*see col. 9, lines 64-67 and col. 10, lines 1-14, where Magee discusses noise estimator to compensate for phase lead or phase lag that can occur as a result of interference, therefore receiver frequency error*) .

It would have been obvious to one of ordinary skill in the art at the time the invention was made to modify the invention of Kleinerman, and have receiver frequency error included in noise estimation, as taught by Magee, thus allowing the phase contribution in the interference be removed, as discussed by Magee (*see col. 9, lines 45-63*).

Consider claim 23, Kleinerman discloses the device of claim 12. Kleinerman discloses the device comprises a mobile station configured for operation in a cellular communication network (*see col. 4, lines 55-65 and col. 5, lines 1-7, where Kleinerman discusses that the apparatus and method are presented in the context of a GSM mobile station*), and wherein the mobile station is configured periodically to obtain compensated noise correlation estimates (*see col. 5, lines 35-50, and col. 6, lines 6-19, where Kleinerman discusses a new channel estimate is calculated from received signal*), and to generate and transmit Channel Quality Indicator reports to the cellular communication network based on the compensated noise correlation estimates (*see*

col. 5, lines 19-35, where Kleinerman teaches maximizing the signal to interference ratio, thus a channel quality indicator, using channel estimation and compensation).

Consider claim 24, Kleinerman discloses the device of claim 12. Kleinerman discloses the device comprises a Wideband Code Division Multiple Access mobile station configured for operation in a Wideband Code Division Multiple Access wireless communication network (*see col. 9, lines 5-55, where Kleinerman teaches the present invention is useful for radio stations such as CDMA and other wireless communication systems*).

2. Claims 4, 18, 21, 28 and 35 are rejected under 35 U.S.C. 103(a) as being unpatentable over Kleinerman et al (US 6470047 B1) in view of Magee et al (US 6563885 B1) and further in view of Wang et al (US 6714585 B1).

Consider claims 4, 18 and 35, the combination of Kleinerman and Magee disclose determining coefficients for a filter in the wireless communication receiver based on the compensated noise correlation estimate (*see col. 18, lines 8-58, where Kleinerman describes determining the coefficients for a filter based on the interference template and the noise vector used for compensation calculation*), however, Kleinerman and Magee do not specifically disclose determining RAKE combining weight for a RAKE receiver circuit. Wang teaches obtaining RAKE combining weight based on noise correlation estimate (*see col. 4, lines 29-57 and col. 10, lines 15-47*).

It would have been obvious to one of ordinary skill in the art at the time the invention was made to modify the invention of Kleinerman and Magee, and have a computation of RAKE

combining weights based on noise correlation estimate for a RAKE receiver, as taught by Wang, thus allowing improvement in received spread spectrum signals that account for interference, as discussed by Wang (*see col. 3, lines 10-41*).

Consider claims 21 and 28, the combination of Kleinerman and Magee disclose the device of claim 12. Kleinerman discloses obtaining reference symbols from a received reference channel signal (*see col. 12, lines 30-50, and col. 14, lines 45-67, where Kleinerman discusses training symbol sequence, therefore reference symbols, contained in an input receive samples*). Magee discloses a channel estimation circuit configured to generation propagation channel estimates from the reference symbols, and wherein the noise correlation estimate comprises a noise covariance matrix generated from the reference symbols and the corresponding propagation channel estimates (*see col. 7, lines 30-65, where Magee teaches a channel estimator, thus a channel estimation circuit, calculates channel estimates using the training tones, thus the reference symbols; Magee teaches the covariance matrix can then be determined*).

Kleinerman and Magee do not specifically disclose the receiver circuit includes or is associated with a RAKE- type receiver. Wang teaches a RAKE- type receiver (see col. 13, lines 10-25).

It would have been obvious to one of ordinary skill in the art at the time the invention was made to modify the invention of Kleinerman and Magee, and have a RAKE-type receiver, as taught by Wang, thus allowing improvement in received spread spectrum signals that account for interference, as discussed by Wang (*see col. 3, lines 10-41*).

Conclusion

3. The prior art made of record and not relied upon is considered pertinent to applicant's disclosure. Vook et al (US 6765969 B1) discloses channel estimation based on pilot sequences, channel gains variables, and a set of weighting coefficients.

Any inquiry concerning this communication or earlier communications from the examiner should be directed to LIHONG YU whose telephone number is (571)270-5147. The examiner can normally be reached on 7:30-5:00.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Nick Corsaro can be reached on (571) 272-2600. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see http://pair-direct.uspto.gov. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

/Lihong Yu/
Examiner, Art Unit 4181

/Nick Corsaro/
Supervisory Patent Examiner, Art Unit 4181

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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/991,878	11/18/2004	Anders Wallen	4015-5251	8906

24112 7590 07/24/2008
COATS & BENNETT, PLLC
1400 Crescent Green, Suite 300
Cary, NC 27518

EXAMINER	
YU, LIHONG	
ART UNIT	PAPER NUMBER
2611	
MAIL DATE	DELIVERY MODE
07/24/2008	PAPER

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

Office Action Summary	**Application No.** 10/991,878	**Applicant(s)** WALLEN, ANDERS	
	Examiner LIHONG YU	**Art Unit** 2611	

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 3 MONTH(S) OR THIRTY (30) DAYS, WHICHEVER IS LONGER, FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

1)☒ Responsive to communication(s) filed on *19 May 2008*.

2a)☒ This action is **FINAL**. 2b)☐ This action is non-final.

3)☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims

4)☒ Claim(s) *1-35* is/are pending in the application.

4a) Of the above claim(s) _____ is/are withdrawn from consideration.

5)☐ Claim(s) _____ is/are allowed.

6)☒ Claim(s) *1-35* is/are rejected.

7)☐ Claim(s) _____ is/are objected to.

8)☐ Claim(s) _____ are subject to restriction and/or election requirement.

Application Papers

9)☐ The specification is objected to by the Examiner.

10)☒ The drawing(s) filed on *18 November 2004* is/are: a)☒ accepted or b)☐ objected to by the Examiner.

Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).

Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

11)☐ The oath or declaration is objected to by the Examiner. Note the attached Office Action or form PTO-152.

Priority under 35 U.S.C. § 119

12)☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

a)☐ All b)☐ Some * c)☐ None of:

1.☐ Certified copies of the priority documents have been received.

2.☐ Certified copies of the priority documents have been received in Application No. _____.

3.☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

* See the attached detailed Office action for a list of the certified copies not received.

Attachment(s)

1) ☐ Notice of References Cited (PTO-892)
2) ☐ Notice of Draftsperson's Patent Drawing Review (PTO-948)
3) ☐ Information Disclosure Statement(s) (PTO/SB/08) Paper No(s)/Mail Date _____.
4) ☐ Interview Summary (PTO-413) Paper No(s)/Mail Date. _____ .
5) ☐ Notice of Informal Patent Application
6) ☐ Other: _____.

DETAILED ACTION

Response to Arguments

1. Applicant's argument, see Remarks, filed on May 19, 2008, with respect to the rejection under 35 U.S.C. 112, first paragraph, has been fully considered and is persuasive. The rejection of claim 12 under 35 U.S.C. 112, first paragraph, has been withdrawn.

2. Applicant's arguments, see Remarks, filed on May 19, 2008, with respect to the rejection under 35 U.S.C. 103(a) as being unpatentable over Kleinerman et al (US 6470047 B1) in view of Magee et al (US 6563885 B1), have been fully considered but are not considered persuasive. The examiner believes that all the arguments of the Applicant have been properly addressed and explained. Thus, the rejections of all of the claims are maintained.

(1) **Applicant's Arguments:**

"Kleinerman does not in fact disclose 'obtaining a compensated noise correlation estimate by removing [an] error term from [a] noise correlation estimate,' as recited in each of the independent claims. Instead, Kleinerman teaches a different approach for compensating a received signal for interference and noise impairments. Importantly, any 'compensation' in Kleinerman is performed directly on the received signal; Kleinerman does not teach the

calculation of an error term arising from a receiver frequency error and compensation of a noise correlation estimate by removing the error term from the noise correlation estimate.

Contrary to the allegations of the Office Action, Kleinerman does not disclose the calculation of an error term corresponding to the noise correlation estimate arising from a receiver frequency error (or any receiver error at all.).

The 'distance' computed in Kleinerman is not an error term arising from a receiver frequency error (or other receiver error). Rather, it is simply a statistic used to determine the best match between a calculated noise vector and several pre-determined interference models representing different types of potential interference that might be encountered.

Furthermore, the 'distance' calculated by Kleinerman is not subsequently 'removed' from Kleinerman's noise vector. Kleinerman in no way discloses removing a calculated error term from a noise correlation estimate to obtain a compensated noise correlation estimate.

Kleinerman does not suggest that filtering the received signal with the selected filter 'removes' the calculated distance from the noise associated with the received signal. It is likely that a filter selected to compensate for that type of interference would yield a noise vector having less of a match, and thus a greater distance value".

Examiner's Response:

Please see col. 6, lines 60-65, where Kleinerman describes calculating a noise vector derived from a received signal; see col. 14, lines 20-30, where Kleinerman describes the noise vector is a channel estimation that could be generated by a correlation method.

Please see col. 6, lines 20-54, where Kleinerman describes calculating interference templates which comprises statistics derived from an interference signal. Kleinerman describes comparing the statistics for the noise vector to the interference templates, therefore an error term would be determined; Kleinerman describes determining an interference template corresponding to a best match between the noise vector statistics and the interference template, that is, the error term is corresponding to the noise vector; see col. 2, lines 4-15, where Kleinerman discuses interference occurs when a radio receiver is tuned to a particular frequency and interference is received from a signal on a nearby frequency, that is, the error term is caused by the receiver that acquires unwanted frequency, or receiver frequency error.

Please see col. 5, lines 20-36, where Kleinerman describes selecting compensation filter in accordance with the determined interference template; see col. 5, lines 35-43, where Kleinerman describes that after compensation filtering, a new channel estimation and noise vector is calculated. That is, the compensation filter has filtered out the error caused by interference. Therefore the new channel estimation and noise vector would not have error term derived from interference. The new channel estimation and noise vector are therefore compensated.

Please see col. 17, lines 15-28, where Kleinerman describes that the minimum distance between the statistic of the noise vector and the interference template is achieved after compensation filtering.

(2) **Applicant's Arguments:**

"Magee does not in fact disclose an error term corresponding to a noise correlation estimation arising from frequency error. At best, Magee discloses that phase lag or phase lead 'can occur as a result of interference during transmission,' and that a noise estimator can implement synchronization, using a 'twiddle factor,' to compensate for the phase lag or lead. (Magee, col. 10, lines 12-14.) Applicant notes that Magee appears to say nothing about frequency error.

Further, Magee does not provide any teaching or suggestion as to whether or how an error term arising from a frequency error (or from a phase lag or lead) might be calculated, or whether or how to remove such an error term from a noise correlation estimate".

Examiner's Response:

Magee, on col. 10, lines 12-14, describes synchronization to compensate phase lag or phase lead. Magee further describes that phase lag or phase lead can occur as a result of high data rates of the signals being transmitted. Therefore phase lag or phase lead is error caused by high data frequency.

Please see Magee at col. 10, lines 25-35, where Magee describes that the noise estimator uses equation 1 to adjust the phase lag or phase lead. Therefore the error caused by phase lag or phase lead would be corrected.

(3) **Applicant's Arguments:**

Kleinerman frequently discusses ‘maximizing’ or ‘improving’ a signal-to-interference ratio, but does not disclose any techniques for calculating such a ratio, much less any techniques that are based on a compensated noise correlation estimate.

Examiner's Response:

As noticed by the Applicant, Kleinerman frequently discusses ‘maximizing’ or ‘improving’ a signal-to-interference ratio. Therefore Kleinerman implicitly discloses calculating such a ratio. Otherwise Kleinerman would not able to tell whether or not the signal-to-interference ratio is improved. Please see col. 5, lines 19-24, where Kleinerman describes that the above mentioned compensation filter would improve the signal-to-interference ratio.

(4) **Applicant’s Arguments:**

“With respect to claims 3 and 15, the Office Action asserts that Kleinerman discloses determining a Channel Quality Indicator from the signal-to-interference ratio for transmission to a supporting wireless communication network. (Office Action, p. 4.) This is simply false. Kleinerman never discusses a channel quality indicator at all, and never discusses the transmission of any parameters to a supporting wireless network”.

Examiner's Response:

Please see col. 5, lines 19-23, where Kleinerman discusses keeping ISI as small as possible. ISI is a Channel Quality Indicator. Please see further at col. 24, lines 38-50, where Kleinerman discusses performance gains, which is another Channel Quality Indicator.

Please see col. 13, lines 38-54, where Kleinerman describes that a reliability metric is generated which has been checked against a threshold. Reliability metric is considered a Channel Quality Indicator.

(5) **Applicant's Arguments:**

"With respect to claims 6 and 29, the Office Action asserts that Kleinerman discloses generating an initial noise correlation matrix based on a received reference channel signal and corresponding propagation channel estimates. (Office Action, p. 4.) This is incorrect, as the Office Action ignores that the claim recites a received reference channel signal. Kleinerman makes no mention of a reference channel, such as a pilot channel".

Examiner's Response:

Please see col. 5, lines 35-40, where Kleinerman discusses a first step of finding the channel estimate and the noise vector from the receive signal. Please see col. 14, line 14-20, lines 45-55, where Kleinerman discusses generating the channel estimate and the noise vector using the received input samples and a training sequence. The channel used to generate this training sequence is considered the reference channel.

(6) **Applicant's Arguments:**

"With respect to claim 23, the Office Action asserts that Kleinerman discloses a device configured to generate and transmit Channel Quality Indicator reports to a cellular communication network. This is false. In support of this allegation, the Office Action

demonstrates only that "Kleinerman teaches maximizing the signal to interference ratio." This falls far short of transmitting a Channel Quality Indicator report to a cellular communication network".

Examiner's Response:

Please see col. 13, lines 38-54, where Kleinerman discusses choosing a compensation filter that is capable of improving the SIR without significantly increasing ISI. Both SIR and ISI are Channel Quality Indicators. Kleinerman also describes that a reliability metric is generated which has been checked against a threshold. Reliability metric is considered another Channel Quality Indicator.

Applicant is reminded that the Examiner is entitled to give the broadest reasonable interpretation to the language of claims. The Examiner is not limited to Applicant's definition which is not specifically set forth in the claims. In re Tanaka et al., 193 USPQ 139, (CCPA) 1977.

Claim Rejections - 35 USC § 103

3. The following is a quotation of 35 U.S.C. 103(a) which forms the basis for all obviousness rejections set forth in this Office action:

> (a) A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negatived by the manner in which the invention was made.

4. Claims 1, 2, 3, 5-17, 19, 20, 22-27, 29-34 are rejected under 35 U.S.C. 103(a) as being unpatentable over Kleinerman et al (US 6470047 B1) in view of Magee et al (US 6563885 B1).

Consider claims 1, 12 and 25:

Kleinerman discloses a method of improving noise estimation processing in a wireless communication receiver (*see abstract and col. 1, lines 16-60, where Kleinerman is discussing a better noise prediction in a wireless communications receiver*) comprising:

- generating a noise correlation estimate (*see Fig. 3*) for a received signal (*see col. 14, lines 14- 54, col. 16, lines 55-64, and col. 13, lines 12-26, where Kleinerman teaches channel estimation using received input samples and correlation method for calculating a noise vector, therefore a noise correlation estimate*);
- calculating an error term corresponding to the noise correlation estimate arising from a receiver error (*see col. 15, lines 12-65, and col. 17, lines 1-28, where Kleinerman discloses comparing the noise vector, thus the noise correlation estimate, with previously generated interference templates*);
- obtaining a compensated noise correlation estimate by removing the error term from the noise correlation estimate (*see col. 5, lines 35-67, where Kleinerman teaches a new channel estimate is calculated after compensation filtering; see col. 18, lines 8-58, where Kleinerman describes determining the coefficients for the compensation filter based on the interference template and the noise vector; see col. 19, lines 12-18, where Kleinerman teaches the compensation filter is operative to filter the received signal, therefore removing the error term*).

Kleinerman does not specifically disclose the receiver frequency error. Magee teaches receiver frequency error (*see col. 9, lines 64-67 and col. 10, lines 1-14, where Magee discusses noise estimator to compensate for phase lead or phase lag that can occur as a result of interference, therefore receiver frequency error*) .

It would have been obvious to one of ordinary skill in the art at the time the invention was made to modify the invention of Kleinerman, and have receiver frequency error included in noise estimation, as taught by Magee, thus allowing the phase contribution in the interference be removed, as discussed by Magee (*see col. 9, lines 45-63*).

Consider claims 2, 13, 26:

Kleinerman discloses calculating a signal-to-interference ratio based on the compensated noise correlation estimate (*see col. 5, lines 19-35, where Kleinerman teaches maximizing the signal to interference ratio using channel estimation and compensation*).

Consider claims 3 and 15:

Kleinerman discloses determining a Channel Quality Indicator from the signal-to-interference ratio for transmission to a supporting wireless communication network (*see col. 12, lines 1-11, col. 13, lines 38-54, and col. 19, lines 18-31, where Kleinerman discusses an interference detector for improving the signal to interference ratio, therefore a channel quality indicator*).

Consider claims 5, 14 and 34:

Kleinerman discloses determining signal quality estimates for the received signal based on the compensated noise correlation estimate (*see col. 5, lines 19-35, where Kleinerman teaches maximizing the signal to interference ratio, therefore signal quality, using channel estimation and compensation*).

Consider claims 6 and 29:

Kleinerman discloses generating an initial noise correlation matrix based on a received reference channel signal and corresponding propagation channel estimates (*see col. 5, lines 35-50, and col. 20, lines 14-42, where Kleinerman is discussing an invention is operative to first find the channel estimate and noise vector, therefore an initial noise correlation matrix, from the receive signal*).

Consider claims 7 and 30:

Kleinerman discloses calculating an error term corresponding to the noise correlation estimate arising from a receiver frequency error comprises calculating an error matrix based on an estimate of the receiver frequency error and a channel correlation matrix determined from the propagation channel estimates (*see col. 19, lines 54-67, and col. 20, lines 1-61, where Kleinerman is discussing an error matrix in the noise vector estimation*).

Consider claims 8, 19 and 31:

Kleinerman discloses obtaining a compensated noise correlation estimate by removing the error term from the noise correlation estimate comprises subtracting the error matrix from the

initial noise correlation matrix to obtain a compensated noise correlation matrix (*see col. 5, lines 35-67, where Kleinerman teaches a new channel estimate and noise vector is calculated after compensation filtering, therefore a compensated noise correlation matrix*).

Consider claims 9, 20, 22 and 32:

Kleinerman in view of Magee discloses the method of claim 1. Magee discloses generating an initial noise covariance matrix based on a received reference channel signal and corresponding propagation channel estimates generated from the received reference channel signal (*see col. 8, lines 42-65, where Magee discusses computation performed on the initial noise estimates for each of the antenna signals, thus received reference channel signal, to provide a covariance matrix; see col. 12, lines 22-65 and col. 19, lines 1-30, where Magee teaches updating the initial noise covariance matrix*).

Consider claim 10, 17 and 33:

Kleinerman in view of Magee discloses the method of generating a noise estimate for a received signal. Magee discloses the reference channel signal is a pilot channel signal (*see col. 7, lines 12-64, where Magee is discussing a channel estimator configured to provide an indication of the magnitude and phase of the training tone (or pilot tone) of the data signals received at the antennas*), and wherein the propagation channel estimates are generated from received pilot symbols (*see col. 4, lines 1-37, where Magee is discussing computing a channel estimate using training tones for use in mitigating the effects of the interference caused by transmission of the received signal*).

Consider claims 11 and 27:

The combination of Kleinerman and Magee disclose calculating an error term corresponding to the noise correlation estimate.

Kleinerman further discloses calculating an error matrix based on determining an estimate of the receiver frequency error over a defined interval of pilot symbols (*see col. 19, lines 54-67, and col. 20, lines 1-61, where Kleinerman is discussing an error matrix in the noise vector estimation; see col. 11, lines 15-23, where Kleinerman describes the channel estimate is obtained using a know training symbol sequence, therefore a defined interval of pilot symbols*), and wherein obtaining a compensated noise correlation estimate by removing the error term from the noise correlation estimate comprises subtracting the error matrix from the initial noise covariance matrix to obtain a compensated noise covariance matrix (*see col. 5, lines 35-67, where Kleinerman teaches a new channel estimate and noise vector is calculated after compensation filtering, therefore a compensated noise correlation matrix*).

Consider claim 16:

The combination of Kleinerman and Magee disclose the device of claim 12. Kleinerman discloses the receiver circuit includes or is associated with an error estimation circuit configured to estimate the receiver error used to calculate the error term (*see col. 15, lines 12-65, and col. 17, lines 1-28, where Kleinerman discloses comparing the noise vector with previously generated interference templates, therefore an error estimation circuit*).

Kleinerman does not specifically disclose the receiver frequency error. Magee teaches receiver frequency error (*see col. 9, lines 64-67 and col. 10, lines 1-14, where Magee discusses noise estimator to compensate for phase lead or phase lag that can occur as a result of interference, therefore receiver frequency error*) .

It would have been obvious to one of ordinary skill in the art at the time the invention was made to modify the invention of Kleinerman, and have receiver frequency error included in noise estimation, as taught by Magee, thus allowing the phase contribution in the interference be removed, as discussed by Magee (*see col. 9, lines 45-63*).

Consider claim 23:

Kleinerman discloses the device of claim 12. Kleinerman discloses the device comprises a mobile station configured for operation in a cellular communication network (*see col. 4, lines 55-65 and col. 5, lines 1-7, where Kleinerman discusses that the apparatus and method are presented in the context of a GSM mobile station*), and wherein the mobile station is configured periodically to obtain compensated noise correlation estimates (*see col. 5, lines 35-50, and col. 6, lines 6-19, where Kleinerman discusses a new channel estimate is calculated from received signal*), and to generate and transmit Channel Quality Indicator reports to the cellular communication network based on the compensated noise correlation estimates (*see col. 5, lines 19-35, where Kleinerman teaches maximizing the signal to interference ratio, thus a channel quality indicator, using channel estimation and compensation*).

Consider claim 24:

Kleinerman discloses the device of claim 12. Kleinerman discloses the device comprises a Wideband Code Division Multiple Access mobile station configured for operation in a Wideband Code Division Multiple Access wireless communication network (*see col. 9, lines 5-55, where Kleinerman teaches the present invention is useful for radio stations such as CDMA and other wireless communication systems*).

5. Claims 4, 18, 21, 28 and 35 are rejected under 35 U.S.C. 103(a) as being unpatentable over Kleinerman et al (US 6470047 B1) in view of Magee et al (US 6563885 B1) and further in view of Wang et al (US 6714585 B1).

Consider claims 4, 18 and 35:

The combination of Kleinerman and Magee disclose determining coefficients for a filter in the wireless communication receiver based on the compensated noise correlation estimate (*see col. 18, lines 8-58, where Kleinerman describes determining the coefficients for a filter based on the interference template and the noise vector used for compensation calculation*), however, Kleinerman and Magee do not specifically disclose determining RAKE combining weight for a RAKE receiver circuit. Wang teaches obtaining RAKE combining weight based on noise correlation estimate (*see col. 4, lines 29-57 and col. 10, lines 15-47*).

It would have been obvious to one of ordinary skill in the art at the time the invention was made to modify the invention of Kleinerman and Magee, and have a computation of RAKE combining weights based on noise correlation estimate for a RAKE receiver, as taught by Wang, thus allowing improvement in received spread spectrum signals that account for interference, as discussed by Wang (*see col. 3, lines 10-41*).

Consider claims 21 and 28:

The combination of Kleinerman and Magee disclose the device of claim 12. Kleinerman discloses obtaining reference symbols from a received reference channel signal (*see col. 12, lines 30-50, and col. 14, lines 45-67, where Kleinerman discusses training symbol sequence, therefore reference symbols, contained in an input receive samples*).

Magee discloses a channel estimation circuit configured to generation propagation channel estimates from the reference symbols, and wherein the noise correlation estimate comprises a noise covariance matrix generated from the reference symbols and the corresponding propagation channel estimates (*see col. 7, lines 30-65, where Magee teaches a channel estimator, thus a channel estimation circuit, calculates channel estimates using the training tones, thus the reference symbols; Magee teaches the covariance matrix can then be determined*).

Kleinerman and Magee do not specifically disclose the receiver circuit includes or is associated with a RAKE- type receiver. Wang teaches a RAKE- type receiver (see col. 13, lines 10-25).

It would have been obvious to one of ordinary skill in the art at the time the invention was made to modify the invention of Kleinerman and Magee, and have a RAKE-type receiver, as taught by Wang, thus allowing improvement in received spread spectrum signals that account for interference, as discussed by Wang (*see col. 3, lines 10-41*).

Conclusion

6. **THIS ACTION IS MADE FINAL.** Applicant is reminded of the extension of time policy as set forth in 37 CFR 1.136(a).

A shortened statutory period for reply to this final action is set to expire THREE MONTHS from the mailing date of this action. In the event a first reply is filed within TWO MONTHS of the mailing date of this final action and the advisory action is not mailed until after the end of the THREE-MONTH shortened statutory period, then the shortened statutory period will expire on the date the advisory action is mailed, and any extension fee pursuant to 37 CFR 1.136(a) will be calculated from the mailing date of the advisory action. In no event, however, will the statutory period for reply expire later than SIX MONTHS from the mailing date of this final action.

Any inquiry concerning this communication or earlier communications from the examiner should be directed to LIHONG YU whose telephone number is (571) 270-5147. The examiner can normally be reached on 8:30 am-7:00 pm Monday-Friday.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Shuwang Liu can be reached on (571) 272-3036. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see http://pair-direct.uspto.gov. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

/Lihong Yu/
Examiner, Art Unit 2611
/Shuwang Liu/
Supervisory Patent Examiner, Art Unit 2611

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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/991,878	11/18/2004	Anders Wallen	4015-5251	8906

24112 7590 12/05/2008
COATS & BENNETT, PLLC
1400 Crescent Green, Suite 300
Cary, NC 27518

EXAMINER	
YU, LIHONG	
ART UNIT	PAPER NUMBER
2611	
MAIL DATE	DELIVERY MODE
12/05/2008	PAPER

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

Notice of Panel Decision from Pre-Appeal Brief Review	Application/Control No. 10/991,878	Applicant(s)/Patent under Reexamination WALLEN, ANDERS	
	SHUWANG LIU	Art Unit 2611	

This is in response to the Pre-Appeal Brief Request for Review filed 20 October 2008.

1. ☐ **Improper Request** – The Request is improper and a conference will not be held for the following reason(s):

   ☐ The Notice of Appeal has not been filed concurrent with the Pre-Appeal Brief Request.
   ☐ The request does not include reasons why a review is appropriate.
   ☐ A proposed amendment is included with the Pre-Appeal Brief request.
   ☐ Other: .

   The time period for filing a response continues to run from the receipt date of the Notice of Appeal or from the mail date of the last Office communication, if no Notice of Appeal has been received.

2. ☐ **Proceed to Board of Patent Appeals and Interferences** – A Pre-Appeal Brief conference has been held. The application remains under appeal because there is at least one actual issue for appeal. Applicant is required to submit an appeal brief in accordance with 37 CFR 41.37. The time period for filing an appeal brief will be reset to be one month from mailing this decision, or the balance of the two-month time period running from the receipt of the notice of appeal, whichever is greater. Further, the time period for filing of the appeal brief is extendible under 37 CFR 1.136 based upon the mail date of this decision or the receipt date of the notice of appeal, as applicable.

   ☐ The panel has determined the status of the claim(s) is as follows:
   Claim(s) allowed: _____.
   Claim(s) objected to: _____.
   Claim(s) rejected: _____.
   Claim(s) withdrawn from consideration: _____.

3. ☐ **Allowable application** – A conference has been held. The rejection is withdrawn and a Notice of Allowance will be mailed. Prosecution on the merits remains closed. No further action is required by applicant at this time.

4. ☒ **Reopen Prosecution** – A conference has been held. The rejection is withdrawn and a new Office action will be mailed. No further action is required by applicant at this time.

All participants:

(1) *SHUWANG LIU*. (3)_____.

(2) *Lihong Yu*. (4)_____.

/Shuwang Liu/
Supervisory Patent Examiner, Art Unit 2611

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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/991,878	11/18/2004	Anders Wallen	4015-5251	8906

24112 7590 02/04/2009

COATS & BENNETT, PLLC
1400 Crescent Green, Suite 300
Cary, NC 27518

EXAMINER	
YU, LIHONG	
ART UNIT	PAPER NUMBER
2611	
MAIL DATE	DELIVERY MODE
02/04/2009	PAPER

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The time period for reply, if any, is set in the attached communication.

PTOL-90A (Rev. 04/07)

Office Action Summary	Application No. 10/991,878	Applicant(s) WALLEN, ANDERS	
	Examiner LIHONG YU	Art Unit 2611	

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

Period for Reply

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Status

1)☒ Responsive to communication(s) filed on *20 October 2008*.

2a)☐ This action is **FINAL**. 2b)☒ This action is non-final.

3)☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims

4)☒ Claim(s) *1-35* is/are pending in the application.

4a) Of the above claim(s) _____ is/are withdrawn from consideration.

5)☐ Claim(s) _____ is/are allowed.

6)☒ Claim(s) *1-35* is/are rejected.

7)☐ Claim(s) _____ is/are objected to.

8)☐ Claim(s) _____ are subject to restriction and/or election requirement.

Application Papers

9)☐ The specification is objected to by the Examiner.

10)☒ The drawing(s) filed on *18 November 2004* is/are: a)☒ accepted or b)☐ objected to by the Examiner.

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Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

11)☐ The oath or declaration is objected to by the Examiner. Note the attached Office Action or form PTO-152.

Priority under 35 U.S.C. § 119

12)☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

a)☐ All b)☐ Some * c)☐ None of:

1.☐ Certified copies of the priority documents have been received.

2.☐ Certified copies of the priority documents have been received in Application No. _____.

3.☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

* See the attached detailed Office action for a list of the certified copies not received.

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4) ☐ Interview Summary (PTO-413) Paper No(s)/Mail Date. _____ .
5) ☐ Notice of Informal Patent Application
6) ☐ Other: _____.

DETAILED ACTION

1. In view of the "Pre-Brief Appeal Conference decision" made on December 05, 2008, the instant application is re-open for prosecution.

Claim Rejections - 35 USC § 103

2. The following is a quotation of 35 U.S.C. 103(a) which forms the basis for all obviousness rejections set forth in this Office action:

> (a) A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negatived by the manner in which the invention was made.

3. Claims 1, 5-7, 12, 16, 23-25, 29 and 30 are rejected under 35 U.S.C. 103(a) as being unpatentable over Mutoh (US 6,807,242 B1) in view of Ashley et al (US 6,889,154 B2).

Consider claims 1, 12 and 25:

Mutoh discloses a method of improving noise estimation processing in a wireless communication receiver (*see Mutoh at the abstract, where Mutoh describes an invention for calculation of noise/correlation value when a frequency error is large; see col. 3, lines 19-33, where Mutoh describes a computer-readable medium embodying a program for execution of the invention*) comprising:

- generating a correlation estimate for a received signal (*see Mutoh at Fig. 1 and col. 4, lines 26-40, where Mutoh describes a correlator 110a that takes a correlation between a measurement signal and a reference signal*);
- calculating an error term corresponding to the correlation estimate arising from a receiver frequency error (*see Mutoh at Fig. 12 and col. 11, lines 18-30, where Mutoh describes obtaining a noise value that is caused by correlation error; Mutoh shows on Fig. 12, the relationship between frequency error and the noise value*); and
- obtaining a compensated correlation estimate by removing the error term from the correlation estimate (*see Mutoh at col. 8, lines 37-45, where Mutoh describes obtaining a correlation-corrected correlation output; see Fig. 14, Fig. 12, frequency error of 2000 Hz, and col. 11, lines 18-30, where Mutoh describes that the correlation correction reduces the noise*).

Mutoh does not specifically disclose the above correlation is a noise correlation. Ashley teaches a noise correlation (*see Ashley at the abstract*).

It would have been obvious to one of ordinary skill in the art at the time the invention was made to modify the invention of Mutoh, and to have a noise correlation, as taught by Ashley, thus allowing for an improved noise predictive filter, as discussed by Ashley (*see Ashley at col. 2, lines 24-60*).

Consider claim 5:

Mutoh in view of Ashley discloses the invention of claim 1 above. Mutoh discloses determining signal quality estimates for the received signal based on the compensated noise correlation estimate (*see Mutoh at Fig. 12, col. 10, lines 59-67, and col. 11, lines 1-31, where*

Mutoh teaches a ratio of noise/correlation value with respect to frequency error after the corrected correlation).

Consider claims 6 and 29:

Mutoh in view of Ashley discloses the invention of claims 1 and 25 above. Mutoh discloses generating an initial correlation matrix based on a received reference channel signal and corresponding propagation channel estimates (*see Mutoh at col. 5, lines 10-26, where Mutoh is discussing output of S0-Sn that are generated from reference signal and added frequency components*).

Mutoh does not specifically disclose the above correlation is a noise correlation. Ashley teaches a noise correlation (*see Ashley at the abstract*).

It would have been obvious to one of ordinary skill in the art at the time the invention was made to modify the invention of Mutoh, and to have a noise correlation, as taught by Ashley, thus allowing for an improved noise predictive filter, as discussed by Ashley (*see Ashley at col. 2, lines 24-60*).

Consider claims 7 and 30:

Mutoh in view of Ashley discloses the invention of claims 6 and 29 above. Mutoh discloses calculating an error matrix based on an estimate of the receiver frequency error and a channel correlation matrix determined from the propagation channel estimates (*see Mutoh at col. 8, lines 2-7, where Mutoh is discussing noise/correlation value ratio with respect to frequency error*).

Consider claim 16:

Mutoh in view of Ashley discloses the invention of claim 12 above. Mutoh discloses the receiver circuit includes or is associated with a frequency error estimation circuit configured to estimate the receiver frequency error used to calculate the error term (*see Mutoh at col. col. 2, lines 16-29, where Mutoh describes generating a frequency error of 1 ppm or near*).

Consider claim 23:

Mutoh in view of Ashley discloses the invention of claim 12 above. Mutoh discloses a mobile station configured for operation in a cellular communication network (*see Mutoh at col. 2, lines 16-29, where Mutoh describes a CDMA radio communication system*), and wherein the mobile station is configured periodically to obtain compensated noise correlation estimates, and to generate and transmit Channel Quality Indicator reports to the cellular communication network based on the compensated noise correlation estimates (*see Mutoh at col. 3, lines 60-65, where Mutoh describes a diagram showing frequency error vs. noise/correlation value ratio*).

Consider claim 24:

Mutoh in view of Ashley discloses the invention of claim 12 above. Mutoh discloses the device comprises a Wideband Code Division Multiple Access mobile station configured for operation in a Wideband Code Division Multiple Access wireless communication network (*see Mutoh at col. 1, lines 25-30, where Mutoh teaches W-CDMA*).

4. Claims 2, 13, 14 and 26 are rejected under 35 U.S.C. 103(a) as being unpatentable over Mutoh (US 6,807,242 B1) in view of Ashley et al (US 6,889,154 B2), as applied to claims 1, 12 and 25 above, and further in view of Kleinerman et al (US 6,470,047 B1).

Consider claims 2, 13, 14 and 26:

Mutoh in view of Ashley discloses the invention of claims 1, 12 and 25 above. Mutoh discloses calculating a noise/correlation ratio based on the compensated correlation estimate (*see Mutoh at Fig. 12 and col. 10, lines 59-67 and col. 11, lines 1-31*).

Mutoh does not specifically disclose: (1), the above correlation is a noise correlation, and (2), the above ratio is a signal-to-interference ratio.

Regarding item (1) above, Ashley teaches a noise correlation (*see Ashley at the abstract*).

It would have been obvious to one of ordinary skill in the art at the time the invention was made to modify the invention of Mutoh, and to have a noise correlation, as taught by Ashley, thus allowing for an improved noise predictive filter, as discussed by Ashley (*see Ashley at col. 2, lines 24-60*).

Regarding item (2) above, Kleinerman teaches calculating a signal-to-interference ratio (*see Kleinerman at col. 5, lines 19-35, where Kleinerman teaches maximizing the signal to interference ratio using channel estimation and compensation*).

It would have been obvious to one of ordinary skill in the art at the time the invention was made to modify the invention of Mutoh, and to calculate a signal-to-interference ratio, as taught by Kleinerman, thus allowing for a radio receiver that is capable of reducing interference, as discussed by Kleinerman (*see Kleinerman at col. 4, lines 46-54*).

5. Claims 3 and 15 are rejected under 35 U.S.C. 103(a) as being unpatentable over Mutoh (US 6,807,242 B1) in view of Ashley et al (US 6,889,154 B2) and Kleinerman et al (US 6,470,047 B1), as applied to claims 2 and 13 above, and further in view of Kim et al (US 7,408,894 B2).

Consider claims 3 and 15:

Mutoh in view of Ashley and Kleinerman discloses the invention of claims 2 and 13 above. Mutoh does not disclose determining a Channel Quality Indicator from the signal-to-interference ratio for transmission to a supporting wireless communication network.

Kim teaches determining a Channel Quality Indicator from a signal-to-interference ratio for transmission to a supporting wireless communication network (*see Kim at col. 5, lines 37-54*).

It would have been obvious to one of ordinary skill in the art at the time the invention was made to modify the invention of Mutoh, and to determining a Channel Quality Indicator from the signal-to-interference ratio for transmission to a supporting wireless communication network, as taught by Kim, thus allowing for improving transmission power control, as discussed by Kim (*see Kim at col. 3, lines 17-42*).

6. Claims 8, 19, 20 and 31 are rejected under 35 U.S.C. 103(a) as being unpatentable over Mutoh (US 6,807,242 B1) in view of Ashley et al (US 6,889,154 B2), as applied to claims 7, 12 and 30 above, and further in view of Ranganath (US 5,239,591).

Consider claims 8, 19 and 31:

Mutoh in view of Ashley discloses the invention of claims 7 and 30 above. Mutoh does not disclose subtracting the error matrix from the initial noise correlation matrix to obtain a compensated noise correlation matrix.

Ranganath teaches subtracting an error from a correlation to obtain a compensated correlation (*see Ranganath at Fig. 6C and col. 10, lines 12-43*).

It would have been obvious to one of ordinary skill in the art at the time the invention was made to modify the invention of Mutoh, and to subtract the error matrix from the initial noise correlation matrix to obtain a compensated noise correlation matrix, as taught by Ranganath, thus allowing for improving the accuracy of the correlation value.

Consider claim 20:

Mutoh in view of Ashley and Ranganath discloses the invention of claim 19 above. Mutoh discloses estimate of the receiver frequency error (*see Mutoh at col. 2, lines 16-28*). Mutoh discloses generate the noise correlation estimate as an initial noise covariance matrix (*see Mutoh at Fig. 1 and col. 4, lines 26-40, where Mutoh describes a correlator 110a that takes a correlation between a measurement signal and a reference signal*), and wherein the compensation circuit is configured to calculate the error term as an error matrix based on the receiver frequency error (*see Mutoh at Fig. 12 and col. 11, lines 18-30, where Mutoh describes obtaining a noise value that is caused by correlation error; Mutoh shows on Fig. 12, the relationship between frequency error and the noise value*), and to obtain the compensated noise correlation estimate as a compensated noise covariance matrix (*see Mutoh at col. 8, lines 37-45, where Mutoh describes obtaining a correlation-corrected correlation output; see Fig. 14, Fig. 12, frequency error of 2000 Hz, and col. 11, lines 18-30, where Mutoh describes that the correlation correction reduces the noise*).

Mutoh does not specifically disclose subtracting the error matrix from the initial noise covariance matrix.

Ranganath teaches subtracting an error from a correlation to obtain a compensated correlation (*see Ranganath at Fig. 6C and col. 10, lines 12-43*).

It would have been obvious to one of ordinary skill in the art at the time the invention was made to modify the invention of Mutoh, and to subtract the error matrix from the initial noise covariance matrix to obtain a compensated noise covariance matrix, as taught by Ranganath, thus allowing for improving the accuracy of the correlation value.

7. Claims 9, 10, 22, 32 and 34 are rejected under 35 U.S.C. 103(a) as being unpatentable over Mutoh (US 6,807,242 B1) in view of Ashley et al (US 6,889,154 B2), as applied to claims 1, 12 and 25 above, and further in view of Magee et al (US 6,563,885 B1)

Consider claims 9, 22 and 32:

Mutoh in view of Ashley discloses the invention of claims 1, 12 and 25 above. Mutoh does not disclose generating an initial noise covariance matrix based on a received reference channel signal and corresponding propagation channel estimates generated from the received reference channel signal.

Magee teaches generating an initial noise covariance matrix based on a received reference channel signal and corresponding propagation channel estimates generated from the received reference channel signal (*see col. 8, lines 42-65, where Magee discusses computation performed on the initial noise estimates for each of the antenna signals, thus received reference channel signal, to provide a covariance matrix; see col. 12, lines 22-65 and col. 19, lines 1-30, where Magee teaches updating the initial noise covariance matrix*).

It would have been obvious to one of ordinary skill in the art at the time the invention was made to modify the invention of Mutoh, and to generate an initial noise covariance matrix based on a received reference channel signal and corresponding propagation channel estimates

generated from the received reference channel signal, as taught by Magee, thus allowing for the phase contribution in the interference be removed, as discussed by Magee (*see Magee at col. 9, lines 45-63*).

Consider claim 10:

Mutoh in view of Ashley and Magee discloses the invention of claim 9 above. Mutoh does not disclose the reference channel signal is a pilot channel signal, and wherein the propagation channel estimates are generated from received pilot symbols.

Magee discloses the reference channel signal is a pilot channel signal (*see col. 7, lines 12-64, where Magee is discussing a channel estimator configured to provide an indication of the magnitude and phase of the training tone (or pilot tone) of the data signals received at the antennas*), and wherein the propagation channel estimates are generated from received pilot symbols (*see col. 4, lines 1-37, where Magee is discussing computing a channel estimate using training tones for use in mitigating the effects of the interference caused by transmission of the received signal*).

It would have been obvious to one of ordinary skill in the art at the time the invention was made to modify the invention of Mutoh, and to have that the reference channel signal is a pilot channel signal, and wherein the propagation channel estimates are generated from received pilot symbols, as taught by Magee, thus allowing for the phase contribution in the interference be removed, as discussed by Magee (*see Magee at col. 9, lines 45-63*).

Consider claim 34:

Mutoh in view of Ashley and Magee discloses the invention of claim 32 above. Mutoh discloses computing a signal quality estimates for the received signal based on the compensated

noise covariance matrix (*see Mutoh at Fig. 12, col. 10, lines 59-67, and col. 11, lines 1-31, where Mutoh teaches a ratio of noise/correlation value with respect to frequency error after the corrected correlation*).

8. Claim 17 is rejected under 35 U.S.C. 103(a) as being unpatentable over Mutoh (US 6,807,242 B1) in view of Ashley et al (US 6,889,154 B2), as applied to claim 16 above, and further in view of Blakeney et al (US 5,490,165).

Consider claim 17:

Mutoh in view of Ashley discloses the invention of claim 16 above. Mutoh does not disclose the frequency error estimation circuit is configured to estimate the receiver frequency error based on determining a symbol phase change over a defined interval of pilot symbols in a pilot signal received in association with the received signal.

Blakeney teaches a frequency error estimation circuit is configured to estimate the receiver frequency error based on determining a symbol phase change over a defined interval of pilot symbols in a pilot signal received in association with the received signal (*see Blakeney at col. 9, lines 48-55*).

It would have been obvious to one of ordinary skill in the art at the time the invention was made to modify the invention of Mutoh, and to have that the frequency error estimation circuit is configured to estimate the receiver frequency error based on determining a symbol phase change over a defined interval of pilot symbols in a pilot signal received in association with the received signal, as taught by Blakeney, thus allowing for a soft handoff, as discussed by Blakeney (*see Blakeney at col. 5, lines 30-37*).

9. Claim 33 is rejected under 35 U.S.C. 103(a) as being unpatentable over Mutoh (US 6,807,242 B1) in view of Ashley et al (US 6,889,154 B2) and Magee et al (US 6,563,885 B1), as applied to claim 32 above, and further in view of Blakeney et al (US 5,490,165).

Consider claim 33:

Mutoh in view of Ashley and Magee discloses the invention of claim 32 above. Mutoh does not disclose program instructions to compute an error matrix based on determining a pilot symbol phase change over a defined interval of pilot symbols received in association with the received signal.

Blakeney teaches compute an error based on determining a pilot symbol phase change over a defined interval of pilot symbols received in association with the received signal (*see Blakeney at col. 9, lines 48-55*).

It would have been obvious to one of ordinary skill in the art at the time the invention was made to modify the invention of Mutoh, and to have program instructions to compute an error matrix based on determining a pilot symbol phase change over a defined interval of pilot symbols received in association with the received signal, as taught by Blakeney, thus allowing for a soft handoff, as discussed by Blakeney (*see Blakeney at col. 5, lines 30-37*).

10. Claim 11 is rejected under 35 U.S.C. 103(a) as being unpatentable over Mutoh (US 6,807,242 B1) in view of Ashley et al (US 6,889,154 B2) and Magee et al (US 6,563,885 B1), as applied to claim 10 above, and further in view of Kleinerman et al (US 6,470,047 B1) and Ranganath (US 5,239,591).

Consider claim 11:

Mutoh in view of Ashley and Magee discloses the invention of claim 10 above. Mutoh discloses estimate of the receiver frequency error (*see Mutoh at col. 2, lines 16-28*). Mutoh does not disclose: (1), calculating an error matrix over a defined interval of pilot symbols, and (2), subtracting the error matrix from the initial noise covariance matrix to obtain a compensated noise covariance matrix.

Regarding item (1) above, Kleinerman teaches calculating an error matrix over a defined interval of pilot symbols (*see col. 19, lines 54-67, and col. 20, lines 1-61, where Kleinerman is discussing an error matrix in the noise vector estimation; see col. 11, lines 15-23, where Kleinerman describes the channel estimate is obtained using a know training symbol sequence, therefore a defined interval of pilot symbols*),

It would have been obvious to one of ordinary skill in the art at the time the invention was made to modify the invention of Mutoh, and to calculate an error matrix over a defined interval of pilot symbols, as taught by Kleinerman, thus allowing for a radio receiver that is capable of reducing interference, as discussed by Kleinerman (*see Kleinerman at col. 4, lines 46-54*).

Regarding item (2) above, Ranganath teaches subtracting an error from a correlation to obtain a compensated correlation (*see Ranganath at Fig. 6C and col. 10, lines 12-43*).

It would have been obvious to one of ordinary skill in the art at the time the invention was made to modify the invention of Mutoh, and to subtract the error matrix from the initial noise covariance matrix to obtain a compensated noise covariance matrix, as taught by Ranganath, thus allowing for improving the accuracy of the correlation value.

11. Claim 27 is rejected under 35 U.S.C. 103(a) as being unpatentable over Mutoh (US 6,807,242 B1) in view of Ashley et al (US 6,889,154 B2) and Kleinerman et al (US 6,470,047 B1), as applied to claim 26 above, and further in view of Blakeney et al (US 5,490,165).

Consider claim 27:

Mutoh in view of Ashley and Kleinerman discloses the invention of claim 26 above. Mutoh does not disclose estimating the receiver frequency error used to calculate the error term based on observing symbol phase changes over a defined interval of reference channel symbols received in conjunction with the received signal.

Blakeney teaches a frequency error estimation circuit is configured to estimate the receiver frequency error based on determining a symbol phase change over a defined interval of pilot symbols in a pilot signal received in association with the received signal (*see Blakeney at col. 9, lines 48-55*).

It would have been obvious to one of ordinary skill in the art at the time the invention was made to modify the invention of Mutoh, and to estimate the receiver frequency error used to calculate the error term based on observing symbol phase changes over a defined interval of reference channel symbols received in conjunction with the received signal, as taught by Blakeney, thus allowing for a soft handoff, as discussed by Blakeney (*see Blakeney at col. 5, lines 30-37*).

12. Claims 4, 18, 21 and 28 are rejected under 35 U.S.C. 103(a) as being unpatentable over Mutoh (US 6,807,242 B1) in view of Ashley et al (US 6,889,154 B2), as applied to claims 1, 12 and 25 above, and further in view of Wang et al (US 6,714,585 B1).

Consider claims 4 and 18:

Mutoh in view of Ashley discloses the invention of claims 1 and 12 above.

Mutoh does not specifically disclose determining RAKE combining weight for a RAKE receiver circuit included in the wireless communication receiver based on the compensated noise correlation estimate.

Wang teaches obtaining RAKE combining weight based on noise correlation estimate (*see Wang at col. 4, lines 29-57 and col. 10, lines 15-47*).

It would have been obvious to one of ordinary skill in the art at the time the invention was made to modify the invention of Mutoh, and to have a computation of RAKE combining weights based on noise correlation estimate for a RAKE receiver, as taught by Wang, thus allowing improvement in received spread spectrum signals that account for interference, as discussed by Wang (*see col. 3, lines 10-41*).

Consider claims 21 and 28:

Mutoh in view of Ashley discloses the invention of claims 12 and 25 above. Mutoh discloses a receiver configured to despread a received reference channel signal to obtain reference symbols (*see Mutoh at Fig. 10 and col. 10, lines 15-31, where Mutoh describes a spreader*), and a channel estimation circuit configured to generation propagation channel estimates from the reference symbols, and wherein the noise correlation estimate comprises a noise covariance matrix generated from the reference symbols and the corresponding

propagation channel estimates (*see Mutoh at col. 8, lines 2-7, where Mutoh is discussing noise/correlation value ratio with respect to frequency error*).

Mutoh does not specifically disclose the receiver circuit includes or is associated with a RAKE- type receiver. Wang teaches a RAKE- type receiver (*see col. 13, lines 10-25*).

It would have been obvious to one of ordinary skill in the art at the time the invention was made to modify the invention of Mutoh, and to have a RAKE-type receiver, as taught by Wang, thus allowing improvement in received spread spectrum signals that account for interference, as discussed by Wang (*see col. 3, lines 10-41*).

13. Claim 35 is rejected under 35 U.S.C. 103(a) as being unpatentable over Mutoh (US 6,807,242 B1) in view of Ashley et al (US 6,889,154 B2) and Magee et al (US 6,563,885 B1), as applied to claim 32 above, and further in view of Wang et al (US 6,714,585 B1).

Consider claim 35:

Mutoh in view of Ashley and Magee discloses the invention of claim 32 above. Mutoh does not disclose computing RAKE combining weights for RAKE receiver processing of the received signal based on the compensated noise covariance matrix.

Wang teaches obtaining RAKE combining weight based on noise correlation estimate (*see Wang at col. 4, lines 29-57 and col. 10, lines 15-47*).

It would have been obvious to one of ordinary skill in the art at the time the invention was made to modify the invention of Mutoh, and to computing RAKE combining weights for RAKE receiver processing of the received signal based on the compensated noise covariance

matrix, as taught by Wang, thus allowing improvement in received spread spectrum signals that account for interference, as discussed by Wang (*see col. 3, lines 10-41*).

Conclusion

Any inquiry concerning this communication or earlier communications from the examiner should be directed to LIHONG YU whose telephone number is (571) 270-5147. The examiner can normally be reached on 8:30 am-7:00 pm Monday-Friday.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Shuwang Liu can be reached on (571) 272-3036. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see http://pair-direct.uspto.gov. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

/Lihong Yu/
Examiner, Art Unit 2611
/Shuwang Liu/
Supervisory Patent Examiner, Art Unit 2611

Case: 13-1622 Document: 25 Page: 106 Filed: 01/22/2014

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10/991,878	11/18/2004	Anders Wallen	4015-5251	8906

24112 7590 07/31/2009
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EXAMINER	
YU, LIHONG	

ART UNIT	PAPER NUMBER
2611	

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Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

Office Action Summary	Application No.	Applicant(s)	
	10/991,878	WALLEN, ANDERS	
	Examiner	**Art Unit**	
	LIHONG YU	2611	

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 3 MONTH(S) OR THIRTY (30) DAYS, WHICHEVER IS LONGER, FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

1)☒ Responsive to communication(s) filed on *04 May 2009*.

2a)☐ This action is **FINAL**. 2b)☒ This action is non-final.

3)☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims

4)☒ Claim(s) *1-35* is/are pending in the application.

4a) Of the above claim(s) _____ is/are withdrawn from consideration.

5)☐ Claim(s) _____ is/are allowed.

6)☒ Claim(s) *1-35* is/are rejected.

7)☐ Claim(s) _____ is/are objected to.

8)☐ Claim(s) _____ are subject to restriction and/or election requirement.

Application Papers

9)☐ The specification is objected to by the Examiner.

10)☒ The drawing(s) filed on *18 November 2004* is/are: a)☒ accepted or b)☐ objected to by the Examiner.

Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).

Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

11)☐ The oath or declaration is objected to by the Examiner. Note the attached Office Action or form PTO-152.

Priority under 35 U.S.C. § 119

12)☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

a)☐ All b)☐ Some * c)☐ None of:

1.☐ Certified copies of the priority documents have been received.

2.☐ Certified copies of the priority documents have been received in Application No. _____.

3.☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

* See the attached detailed Office action for a list of the certified copies not received.

Attachment(s)

1) ☒ Notice of References Cited (PTO-892)
2) ☐ Notice of Draftsperson's Patent Drawing Review (PTO-948)
3) ☐ Information Disclosure Statement(s) (PTO/SB/08) Paper No(s)/Mail Date _____.
4) ☐ Interview Summary (PTO-413) Paper No(s)/Mail Date. _____ .
5) ☐ Notice of Informal Patent Application
6) ☐ Other: _____.

DETAILED ACTION

Response to Arguments

1. Applicant's arguments with respect to claim rejections under 35 USC 103 have been considered but are moot in view of the new ground of rejection.

Claim Rejections - 35 USC § 103

2. The following is a quotation of 35 U.S.C. 103(a) which forms the basis for all obviousness rejections set forth in this Office action:

> (a) A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negatived by the manner in which the invention was made.

3. Claims 1, 2, 5-8, 12-14, 16, 19, 23, 25, 26 and 29-31 are rejected under 35 U.S.C. 103(a) as being unpatentable over Russell (US 4,477,912).

Consider claims 1, 12 and 25:

Russell discloses a method of improving noise estimation processing in a wireless communication receiver (*see Russell at col. 2, lines 35-43, where Russell describes an invention for data communications between radio transmitters and receivers employing correlation detection techniques; see the abstract, where Russell describes the undesirable signal variations are eliminated from the output of the correlation detection*) comprising:

- generating a correlation estimate for a received signal (*see Russell at Fig. 2 and col. 9, lines 3-38, where Russell describes a received signal is fed to a correlation detector 53*);
- calculating an error term corresponding to the correlation estimate arising from a receiver frequency error (*see Russell at the abstract, col. 2, lines 44-56 and col. 11, lines 40-46, where Russell describes that undesirable signal variations in the output of the correlation detector 53 is detected, which is the effects of the frequency translation error*); and
- obtaining a compensated correlation estimate by removing the error term from the correlation estimate (*see Russell at the abstract, col. 2, lines 44-56 and col. 11, lines 40-46, where Russell describes that undesirable signal variations in the output of the correlation detector 53 caused by a frequency translation error introduced in the transmission and reception of the pseudo random binary code is eliminated by a feedback system which detects the effects of the frequency translation error at the output of the correlation detector 53*).

Russell discloses the above correlation is pseudo random signal correlation (*see Russell at col. 7, lines 55-67*) instead of noise correlation. The pseudo random signal disclosed by Russell is a pseudo noise signal and it is well known to one of ordinary skill in the art that pseudo noise has the same characteristics as noise. Therefore, it would have been obvious to one of ordinary skill in the art at the time the invention was made to utilizing Russell's invention in the noise correlation.

Consider claims 2, 13, 14 and 26:

Russell discloses the invention of claims 1, 12 and 25 above. Russell discloses calculating a signal-to-interference ratio based on the compensated noise correlation estimate (*see Russell at col. 3, lines 12-19, where Russell describes the minimization of distortion of the pseudo random binary code words such that signal-to-interference ratios are not degraded significantly*).

Consider claim 5:

Russell discloses the invention of claim 1 above. Russell discloses determining signal quality estimates for the received signal based on the compensated noise correlation estimate (*see Russell at col. 14, lines 26-31, where Russell teaches improving the quality of the correlation detector output*).

Consider claims 6 and 29:

Russell discloses the invention of claims 1 and 25 above. Russell discloses generating an initial correlation matrix based on a received reference channel signal and corresponding propagation channel estimates (*see Russell at col. 8, lines 59-68, where Russell is discussing correlates incoming pseudo random binary code words with similar locally generated reference pseudo random binary code words*).

Consider claims 7 and 30:

Russell discloses the invention of claims 6 and 29 above. Russell discloses calculating an error matrix based on an estimate of the receiver frequency error and a channel correlation matrix determined from the propagation channel estimates (*see Russell at the abstract, col. 2, lines 44-56 and col. 11, lines 40-46, where Russell describes that undesirable signal variations,*

that is an error matrix, in the output of the correlation detector 53 is detected, which is the effects of the frequency translation error).

Consider claims 8, 19 and 31:

Russell discloses the invention of claims 7 and 30 above. Russell discloses subtracting the error matrix from the initial noise correlation matrix to obtain a compensated noise correlation matrix (*see Russell at col. 10, lines 2-13, where Russell describes the unlike bits are subtracted from the sum of product of the like bits to produce the correlation between incoming pseudo random binary code word and the locally generated reference pseudo random binary code word*).

Consider claim 16:

Russell discloses the invention of claim 12 above. Russell discloses the receiver circuit includes or is associated with a frequency error estimation circuit configured to estimate the receiver frequency error used to calculate the error term (*see Russell at col. 15, lines 14-18, where Russell describes determining a frequency translation error*).

Consider claim 23:

Russell discloses the invention of claim 12 above. Russell discloses a mobile station configured for operation in a cellular communication network (*see Russell at col. 2, lines 35-43, where Russell describes the invention is for high frequency SSB radio transmitter and receivers which can be used on cellular network*), and wherein the mobile station is configured periodically to obtain compensated noise correlation estimates, and to generate and transmit Channel Quality Indicator reports to the cellular communication network based on the

compensated noise correlation estimates (*see Russell at Fig. 4a, 4b and col. 13, lines 3-19, where Russell describes diagrams showing the output from the correlation detector 53*).

4. Claims 3 and 15 are rejected under 35 U.S.C. 103(a) as being unpatentable over Russell (US 4,477,912), as applied to claims 2 and 13 above, and in view of Kim et al (US 7,408,894 B2).

Consider claims 3 and 15:

Russell discloses the invention of claims 2 and 13 above. Russell does not disclose determining a Channel Quality Indicator from the signal-to-interference ratio for transmission to a supporting wireless communication network.

Kim teaches determining a Channel Quality Indicator from a signal-to-interference ratio for transmission to a supporting wireless communication network (*see Kim at col. 5, lines 37-54*).

It would have been obvious to one of ordinary skill in the art at the time the invention was made to modify the invention of Russell, and to determining a Channel Quality Indicator from the signal-to-interference ratio for transmission to a supporting wireless communication network, as taught by Kim, thus allowing for improving transmission power control, as discussed by Kim (*see Kim at col. 3, lines 17-42*).

5. Claims 4 and 18 are rejected under 35 U.S.C. 103(a) as being unpatentable over Russell (US 4,477,912), as applied to claims 1, 12 and 25 above, and in view of Wang et al (US 6,714,585 B1).

Consider claims 4 and 18:

Russell discloses the invention of claims 1 and 12 above. Russell does not specifically disclose determining RAKE combining weight for a RAKE receiver circuit included in the wireless communication receiver based on the compensated noise correlation estimate.

Wang teaches obtaining RAKE combining weight based on noise correlation estimate (*see Wang at col. 4, lines 29-57 and col. 10, lines 15-47*).

It would have been obvious to one of ordinary skill in the art at the time the invention was made to modify the invention of Russell, and to have a computation of RAKE combining weights based on noise correlation estimate for a RAKE receiver, as taught by Wang, thus allowing improvement in received spread spectrum signals that account for interference, as discussed by Wang (*see col. 3, lines 10-41*).

6. Claims 21 and 28 are rejected under 35 U.S.C. 103(a) as being unpatentable over Russell (US 4,477,912), as applied to claims 12 and 25 above, and in view of Bottomley et al (US 2005/0069023 A1).

Consider claims 21 and 28:

Russell discloses the invention of claims 12 and 25 above. Russell does not disclose a RAKE-type receiver configured to despread a received reference channel signal to obtain reference symbols, and a channel estimation circuit configured to generation propagation channel estimates from the reference symbols, and wherein the noise correlation estimate comprises a noise covariance matrix generated from the reference symbols and the corresponding propagation channel estimates.

Bottomley teaches a RAKE-type receiver configured to despread a received reference channel signal to obtain reference symbols, and a channel estimation circuit configured to generation propagation channel estimates from the reference symbols (*see Bottomley at paragraph 0029, where Bottomley describes that a RAKE processor can be configured to generate estimates of channel coefficient cross-correlations using received pilot symbols, that is reference symbols*), and wherein the noise correlation estimate comprises a noise covariance matrix generated from the reference symbols and the corresponding propagation channel estimates (*see Bottomley at paragraph 0052, where Bottomley describes that the noise covariance is depending on channel estimation error statistics which is calculated from the pilot symbols*).

It would have been obvious to one of ordinary skill in the art at the time the invention was made to modify the invention of Russell, and to have a RAKE-type receiver configured to despread a received reference channel signal to obtain reference symbols, and a channel estimation circuit configured to generation propagation channel estimates from the reference symbols, wherein the noise correlation estimate comprises a noise covariance matrix generated from the reference symbols and the corresponding propagation channel estimates, as taught by Bottomley, thus allowing for improvement in signal-to-noise ratio of a RAKE receiver, as discussed by Bottomley (*see Bottomley paragraph 0003*).

7. Claims 9, 10, 22, 32 and 34 are rejected under 35 U.S.C. 103(a) as being unpatentable over Russell (US 4,477,912), as applied to claims 1, 12 and 25 above, and in view of Magee et al (US 6,563,885 B1)

Consider claims 9, 22 and 32:

Russell discloses the invention of claims 1, 12 and 25 above. Russell does not disclose generating an initial noise covariance matrix based on a received reference channel signal and corresponding propagation channel estimates generated from the received reference channel signal.

Magee teaches generating an initial noise covariance matrix based on a received reference channel signal and corresponding propagation channel estimates generated from the received reference channel signal (*see col. 8, lines 42-65, where Magee discusses computation performed on the initial noise estimates for each of the antenna signals, thus received reference channel signal, to provide a covariance matrix; see col. 12, lines 22-65 and col. 19, lines 1-30, where Magee teaches updating the initial noise covariance matrix*).

It would have been obvious to one of ordinary skill in the art at the time the invention was made to modify the invention of Russell, and to generate an initial noise covariance matrix based on a received reference channel signal and corresponding propagation channel estimates generated from the received reference channel signal, as taught by Magee, thus allowing for the phase contribution in the interference be removed, as discussed by Magee (*see Magee at col. 9, lines 45-63*).

Consider claim 10:

Russell in view of Magee discloses the invention of claim 9 above. Russell does not disclose the reference channel signal is a pilot channel signal, and wherein the propagation channel estimates are generated from received pilot symbols.

Magee discloses a pilot channel signal (*see col. 7, lines 12-64, where Magee is discussing a channel estimator configured to provide an indication of the magnitude and phase of the training tone (or pilot tone) of the data signals received at the antennas*), and propagation channel estimates are generated from received pilot symbols (*see col. 4, lines 1-37, where Magee is discussing computing a channel estimate using training tones for use in mitigating the effects of the interference caused by transmission of the received signal*).

It would have been obvious to one of ordinary skill in the art at the time the invention was made to modify the invention of Russell, and to have a pilot channel signal, and wherein the propagation channel estimates are generated from received pilot symbols, as taught by Magee, thus allowing for the phase contribution in the interference be removed, as discussed by Magee (*see Magee at col. 9, lines 45-63*).

Consider claim 34:

Russell in view of Magee discloses the invention of claim 32 above. Russell discloses computing a signal quality estimates for the received signal based on the compensated noise covariance matrix (*see Russell at col. 14, lines 26-31, where Russell teaches improving the quality of the correlation detector output*).

8. Claim 11 is rejected under 35 U.S.C. 103(a) as being unpatentable over Russell (US 4,477,912) in view of Magee et al (US 6,563,885 B1), as applied to claim 10 above, and further in view of Kleinerman et al (US 6,470,047 B1) and Ranganath (US 5,239,591).

Consider claim 11:

Russell in view of Magee discloses the invention of claim 10 above. Russell does not disclose: (1), calculating an error matrix over a defined interval of pilot symbols, and (2), subtracting the error matrix from the initial noise covariance matrix to obtain a compensated noise covariance matrix.

Regarding item (1) above, Kleinerman teaches calculating an error matrix over a defined interval of pilot symbols (*see col. 19, lines 54-67, and col. 20, lines 1-61, where Kleinerman is discussing an error matrix in the noise vector estimation; see col. 11, lines 15-23, where Kleinerman describes the channel estimate is obtained using a know training symbol sequence, therefore a defined interval of pilot symbols*),

It would have been obvious to one of ordinary skill in the art at the time the invention was made to modify the invention of Russell, and to calculate an error matrix over a defined interval of pilot symbols, as taught by Kleinerman, thus allowing for a radio receiver that is capable of reducing interference, as discussed by Kleinerman (*see Kleinerman at col. 4, lines 46-54*).

Regarding item (2) above, Ranganath teaches subtracting an error from a correlation to obtain a compensated correlation (*see Ranganath at Fig. 6C and col. 10, lines 12-43*).

It would have been obvious to one of ordinary skill in the art at the time the invention was made to modify the invention of Russell, and to subtract the error matrix from the initial noise covariance matrix to obtain a compensated noise covariance matrix, as taught by Ranganath, thus allowing for improving the accuracy of the correlation value.

9. Claim 17 is rejected under 35 U.S.C. 103(a) as being unpatentable over Russell (US 4,477,912), as applied to claim 16 above, and in view of Blakeney et al (US 5,490,165).

Consider claim 17:

Russell in view of Ashley discloses the invention of claim 16 above. Russell does not disclose estimating the receiver frequency error based on determining a symbol phase change over a defined interval of pilot symbols in a pilot signal received in association with the received signal.

Blakeney teaches estimating the receiver frequency error based on determining a symbol phase change over a defined interval of pilot symbols in a pilot signal received in association with the received signal (*see Blakeney at col. 9, lines 48-55*).

It would have been obvious to one of ordinary skill in the art at the time the invention was made to modify the invention of Russell, and to estimate the receiver frequency error based on determining a symbol phase change over a defined interval of pilot symbols in a pilot signal received in association with the received signal, as taught by Blakeney, thus allowing for a soft handoff, as discussed by Blakeney (*see Blakeney at col. 5, lines 30-37*).

10. Claim 20 is rejected under 35 U.S.C. 103(a) as being unpatentable over Russell (US 4,477,912), as applied to claim 19 above, and in view of Ranganath (US 5,239,591).

Consider claim 20:

Russell discloses the invention of claim 19 above. Russell discloses calculating the error term as an error matrix based on the receiver frequency error (*see Russell at the abstract*).

Russell does not disclose subtracting the error matrix from the initial noise covariance matrix to obtain a compensated noise covariance matrix.

Ranganath teaches subtracting an error from a correlation to obtain a compensated correlation (*see Ranganath at Fig. 6C and col. 10, lines 12-43*).

It would have been obvious to one of ordinary skill in the art at the time the invention was made to modify the invention of Russell, and to subtract the error matrix from the initial noise covariance matrix to obtain a compensated noise covariance matrix, as taught by Ranganath, thus allowing for improving the accuracy of the correlation value.

11. Claim 24 is rejected under 35 U.S.C. 103(a) as being unpatentable over Russell (US 4,477,912), as applied to claim 12 above, and in view of Mutoh (US 6,807,242 B1).

Consider claim 24:

Russell discloses the invention of claim 12 above. Russell does not disclose a Wideband Code Division Multiple Access mobile station.

Mutoh discloses a Wideband Code Division Multiple Access mobile station configured for operation in a Wideband Code Division Multiple Access wireless communication network (*see Mutoh at col. 1, lines 25-30, where Mutoh teaches W-CDMA*).

It would have been obvious to one of ordinary skill in the art at the time the invention was made to modify the invention of Russell, and to have a Wideband Code Division Multiple Access mobile station, as taught by Mutoh, thus allowing for improved wireless network performance.

12. Claim 33 is rejected under 35 U.S.C. 103(a) as being unpatentable over Russell (US 4,477,912) in view of Magee et al (US 6,563,885 B1), as applied to claim 32 above, and further in view of Blakeney et al (US 5,490,165).

Consider claim 33:

Russell in view of Magee discloses the invention of claim 32 above. Russell does not disclose program instructions to compute an error matrix based on determining a pilot symbol phase change over a defined interval of pilot symbols received in association with the received signal.

Blakeney teaches compute an error based on determining a pilot symbol phase change over a defined interval of pilot symbols received in association with the received signal (*see Blakeney at col. 9, lines 48-55*).

It would have been obvious to one of ordinary skill in the art at the time the invention was made to modify the invention of Russell, and to have program instructions to compute an error matrix based on determining a pilot symbol phase change over a defined interval of pilot symbols received in association with the received signal, as taught by Blakeney, thus allowing for a soft handoff, as discussed by Blakeney (*see Blakeney at col. 5, lines 30-37*).

13. Claim 27 is rejected under 35 U.S.C. 103(a) as being unpatentable over Russell (US 4,477,912) in view of Blakeney et al (US 5,490,165).

Consider claim 27:

Russell discloses the invention of claim 26 above. Russell does not disclose estimating the receiver frequency error used to calculate the error term based on observing symbol phase

changes over a defined interval of reference channel symbols received in conjunction with the received signal**.**

Blakeney teaches a frequency error estimation circuit is configured to estimate the receiver frequency error based on determining a symbol phase change over a defined interval of pilot symbols in a pilot signal received in association with the received signal (*see Blakeney at col. 9, lines 48-55*).

It would have been obvious to one of ordinary skill in the art at the time the invention was made to modify the invention of Russell, and to estimate the receiver frequency error used to calculate the error term based on observing symbol phase changes over a defined interval of reference channel symbols received in conjunction with the received signal, as taught by Blakeney, thus allowing for a soft handoff, as discussed by Blakeney (*see Blakeney at col. 5, lines 30-37*).

14. Claim 35 is rejected under 35 U.S.C. 103(a) as being unpatentable over Russell (US 4,477,912) in view of Magee et al (US 6,563,885 B1), as applied to claim 32 above, and further in view of Wang et al (US 6,714,585 B1).

Consider claim 35:

Russell in view of Magee discloses the invention of claim 32 above. Russell does not disclose computing RAKE combining weights for RAKE receiver processing of the received signal based on the compensated noise covariance matrix.

Wang teaches obtaining RAKE combining weight based on noise correlation estimate (*see Wang at col. 4, lines 29-57 and col. 10, lines 15-47*).

It would have been obvious to one of ordinary skill in the art at the time the invention was made to modify the invention of Russell, and to compute RAKE combining weights for RAKE receiver processing of the received signal based on the compensated noise covariance matrix, as taught by Wang, thus allowing improvement in received spread spectrum signals that account for interference, as discussed by Wang (*see col. 3, lines 10-41*).

Conclusion

Any inquiry concerning this communication or earlier communications from the examiner should be directed to LIHONG YU whose telephone number is (571) 270-5147. The examiner can normally be reached on 8:30 am-7:00 pm Monday-Friday.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Shuwang Liu can be reached on (571) 272-3036. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see http://pair-direct.uspto.gov. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

/Lihong Yu/
Examiner, Art Unit 2611
/Shuwang Liu/
Supervisory Patent Examiner, Art Unit 2611

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE
BEFORE THE BOARD OF PATENT APPEALS AND INTERFERENCES

In re Application of
Wallén

Serial No.: **10/991,878**

Filed: **November 18, 2004**

For: **Method and Apparatus to Compensate for Receiver Frequency Error in Noise Estimation Processing**

Docket No: **4015-5251**

PATENT PENDING

Examiner: Lihong Yu

Group Art Unit: 4181

Confirmation No.: 8906

Mail Stop Appeal Brief-Patents
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

CERTIFICATE OF MAILING OR TRANSMISSION [37 CFR 1.8(a)]

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Date

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Dear Sir or Madam:

This appeal brief is filed within one month of the Notice of Panel Decision from Pre-Appeal Brief Review mailed 13 January 2010. An appeal brief fee of $540 accompanies this appeal brief. Thus, no additional fees are believed to be due. However, if any further fees or charges are required, the Commissioner is hereby authorized to charge them to Deposit Account 18-1167.

APPEAL BRIEF

(I.) REAL PARTY IN INTEREST

The real party in interest is Telefonaktiebolaget LM Ericsson (publ), a Swedish company.

(II.) RELATED APPEALS AND INTERFERENCES

To the best of Appellant's knowledge, there are no related appeals or interferences.

(III.) STATUS OF CLAIMS

Claims 1-35 are pending. Claims 1-35 stand rejected by the Examiner in an office action dated 31 July 2009 (hereinafter, the "Pending Office Action"). Appellant appeals the rejection of claims 1-35.

(IV.) STATUS OF AMENDMENTS

No amendments have been submitted subsequent to the Pending Office Action.

(V.) SUMMARY OF CLAIMED SUBJECT MATTER

The pending claims under appeal consist of claims 1-35, including independent claims 1, 12, and 25. No claim under appeal is in means-plus-function or step-plus-function form pursuant to 35 U.S.C. §112, ¶ 6. Thus, only the independent claims under appeal are summarized below, in accordance with 37 C.F.R. § 41.37(v) and (vii).

signal for Russell's reference pseudorandom binary code would not yield an estimate of the noise present in the received signal. Instead, substituting a noise signal would simply cause Russell's correlation detector to generate an even <u>noisier</u> signal.

Each of independent claims 1, 12, and 25 recite details of a technique for improving noise estimation processing in a wireless communication receiver. This technique includes the generation of an estimate of <u>noise correlations</u> in a received signal, the calculation of an error term corresponding to the <u>noise correlation</u> estimate and arising from a receiver frequency error, and the obtaining of a compensated <u>noise correlation</u> estimate by removing the error term from the initial <u>noise correlation</u> estimate. Because the only common ground between Russell and the pending claims is that each is directed generally to wireless receivers and that each uses the word "correlation," the rejections of independent claims 1, 12, and 25 are without merit, and should be reversed. Furthermore, because the rejections of all the dependent claims depend upon these same grounds of rejection, all of the pending rejections should be reversed.

<u>2. The rejections of dependent claims 2, 13, 14, and 26 are without any basis in fact, as Russell does not teach or suggest the calculation of a signal quality estimate at all, much less a signal quality estimate based on a compensated noise correlation estimate.</u>

Each of dependent claims 2, 13, 14, and 26 is directed to the estimation of a signal quality for the received signal, based on the compensated noise correlation estimate of the corresponding parent claim. Claims 2 and 14 are specifically directed to

the estimation of a signal-to-noise ratio based on the compensated noise correlation estimate. The Pending Office Action's finding that these features are disclosed in Russell is utterly without merit.

The Pending Office Action asserts that "Russell describes the minimization of distortion of the pseudo random binary code words such that signal-to-interference ratios are not degraded significantly." (Pending Office Action at p. 4.) This is true – the goal of Russell's receiver (and of receivers generally) is process received signals without the undue addition of distortion. However, this is not what claims 2, 13, 14, and 26 recite. These claims are directed to the calculation of a signal quality, based on a specific quantity, i.e., the compensated noise correlation estimate of the parent claim. Russell merely states that an objective of the receiver techniques disclosed therein is to avoid degrading the signal-to-interference ratio of a received signal. This signal-to-interference ratio is an inherent quality of the received signal. Nothing in Russell suggests that this inherent quality is estimated at all. And nothing in Russell suggests that any signal quality, much less a signal-to-interference ratio, can or should be calculated based on a compensated noise correlation estimate.

Because the rejections of claims 2, 13, 14, and 26 are utterly without merit, they should be reversed.

3. The rejection of dependent claim 5 is without any basis in fact, as Russell does not teach or suggest the determination of a signal quality estimate at all, much less a signal quality estimate based on a compensated noise correlation estimate.

Dependent claim 5 recites the determining of signal quality estimates for the received signal based on the compensated noise correlation estimate of claim 1. Thus, claim 5 is directed to the same general subject matter of claims 2, 13, 14, and 26, namely, the estimation of a signal quality based on the compensated noise correlation estimate. Inexplicably, the Pending Office Action (at p. 4) provides a separate rationale for the rejection of claim 5, citing a portion of Russell that mentions a "detranslation loop" that "improves the quality of the correlation detector output..." (Russell at col. 14, lines 26-31.) Of course, this rejection is improper for the same reason discussed above – the mere mention of "quality" does not anticipate or render obvious the determination of a signal quality estimate described in claim 5. The rejection of claim 5, based on nothing more than a word-matching exercise, should be reversed.

4. The rejections of dependent claims 6 and 29 are without any basis in fact, as Russell does not teach or suggest the generating of an initial noise correlation matrix based on a received reference channel signal and corresponding propagation channel estimates.

The Pending Office Action's rejection of claims 6 and 29 appears to be based entirely on the fact that Russell happens to use the word "reference." *See* Office Action at p. 4; *see also* Russell at col. 8, lines 59-68. In fact, Russell does not teach or suggest the generation of an initial noise correlation matrix, or any matrix at all. Russell

does not make any mention of a reference channel, or a received reference channel signal. And Russell does not make any mention of propagation channel estimates. Because Russell only discloses one word of the claims, but none of the actual features of the claims, the rejections of claims 6 and 29 should be reversed.

<u>5. The rejections of dependent claims 7 and 30 are without any basis in fact, as Russell does not teach or suggest the calculating of an error matrix or a channel correlation matrix.</u>

Claims 7 and 30 depend from claims 6 and 29, respectively, and are thus improper for the reasons given immediately above. However, the specific findings with respect to these claims are also erroneous, and should be reversed.

The Pending Office Action's rejection of claims 7 and 30 are based on an alleged statement of fact that appears to be fabricated from thin air. According to the Pending Office Action, "Russell describes that undesirable signal variations, <u>that is an error matrix</u>, in the output of the correlation detector 53 is detected, which is the effects of the frequency translation error." (Pending Office Action at pp. 4-5, emphasis added.) Leaving aside the fact that the rejection entirely ignores the recited "channel correlation matrix" of the claims, the Pending Office Action's equating of Russell's "undesirable signal variations" with the claimed "error matrix" is without basis in Russell or in fact. The rejections of claims 7 and 30 should be reversed.

<u>6. The rejections of dependent claims 8, 19, and 31 are without any basis in fact.</u>

(VIII.) CLAIMS APPENDIX

1. A method of improving noise estimation processing in a wireless communication receiver comprising:

generating a noise correlation estimate for a received signal;

calculating an error term corresponding to the noise correlation estimate arising from a receiver frequency error; and

obtaining a compensated noise correlation estimate by removing the error term from the noise correlation estimate.

2. The method of claim 1, further comprising calculating a signal-to-interference ratio based on the compensated noise correlation estimate.

3. The method of claim 2, further comprising determining a Channel Quality Indicator from the signal-to-interference ratio for transmission to a supporting wireless communication network.

4. The method of claim 1, further comprising determining RAKE combining weights for a RAKE receiver circuit included in the wireless communication receiver based on the compensated noise correlation estimate.

5. The method of claim 1, further comprising determining signal quality estimates for the received signal based on the compensated noise correlation estimate.

6. The method of claim 1, wherein generating a noise correlation estimate for a received signal comprises generating an initial noise correlation matrix based on a received reference channel signal and corresponding propagation channel estimates.

7. The method of claim 6, wherein calculating an error term corresponding to the noise correlation estimate arising from a receiver frequency error comprises calculating an error matrix based on an estimate of the receiver frequency error and a channel correlation matrix determined from the propagation channel estimates.

8. The method of claim 7, wherein obtaining a compensated noise correlation estimate by removing the error term from the noise correlation estimate comprises subtracting the error matrix from the initial noise correlation matrix to obtain a compensated noise correlation matrix.

9. The method of claim 1, wherein generating a noise correlation estimate for a received signal comprises generating an initial noise covariance matrix based on a received reference channel signal and corresponding propagation channel estimates generated from the received reference channel signal.

10. The method of claim 9, wherein the reference channel signal is a pilot channel signal, and wherein the propagation channel estimates are generated from received pilot symbols.

11. The method of claim 10, wherein calculating an error term corresponding to the noise correlation estimate comprises calculating an error matrix based on determining an estimate of the receiver frequency error over a defined interval of pilot symbols, and wherein obtaining a compensated noise correlation estimate by removing the error term from the noise correlation estimate comprises subtracting the error matrix from the initial noise covariance matrix to obtain a compensated noise covariance matrix.

12. A wireless communication device comprising a receiver circuit configured to:

generate a noise correlation estimate for a received signal;

calculate an error term corresponding to the noise correlation estimate arising from a receiver frequency error; and

obtain a compensated noise correlation estimate by removing the error term from the noise correlation estimate.

13. The device of claim 12, wherein the receiver circuit includes a signal quality estimation circuit configured to estimate a signal quality for the received signal based on the compensated noise correlation estimate.

14. The device of claim 13, wherein the signal quality estimation circuit is configured to calculate a signal-to-interference ratio based on the compensated noise correlation estimate, such that the calculated signal-to-interference ratio is compensated for the receiver frequency error.

15. The device of claim 14, wherein the signal quality estimation circuit is configured to determine a Channel Quality Indicator value from the calculated signal-to-interference ratio, such that the Channel Quality Indictor value is compensated for the receiver frequency error.

16. The device of claim 12, wherein the receiver circuit includes or is associated with a frequency error estimation circuit configured to estimate the receiver frequency error used to calculate the error term.

17. The device of claim 16, wherein the frequency error estimation circuit is configured to estimate the receiver frequency error based on determining a symbol phase change over a defined interval of pilot symbols in a pilot signal received in association with the received signal.

18. The device of claim 12, further comprising a RAKE receiver operatively associated with the receiver circuit, said RAKE receiver configured to calculate RAKE combining weights based on the compensated noise correlation estimate, such that the RAKE combining weights are compensated for the receiver frequency error.

19. The device of claim 12, wherein the receiver circuit includes a noise correlation estimation circuit configured to generate the noise correlation estimate, and a compensation circuit configured to calculate the error term and to obtain the compensated noise correlation estimate.

20. The device of claim 19, wherein the noise correlation estimation circuit is configured to generate the noise correlation estimate as an initial noise covariance matrix, and wherein the compensation circuit is configured to calculate the error term as an error matrix based on the receiver frequency error, and to obtain the compensated noise correlation estimate as a compensated noise covariance matrix by subtracting the error matrix from the initial noise covariance matrix.

21. The device of claim 12, wherein the receiver circuit includes or is associated with a RAKE-type receiver configured to despread a received reference channel signal to obtain reference symbols, and a channel estimation circuit configured to generation propagation channel estimates from the reference symbols, and wherein the noise correlation estimate comprises a noise covariance matrix generated from the reference symbols and the corresponding propagation channel estimates.

22. The device of claim 12, wherein the receiver circuit is configured to generate the noise correlation estimate as a noise covariance matrix, and to obtain the compensated noise correlation estimate as a compensated noise covariance matrix based on subtracting an error matrix from the noise correlation matrix, wherein the error matrix is based on the receiver frequency error.

23. The device of claim 12, wherein the device comprises a mobile station configured for operation in a cellular communication network, and wherein the mobile station is configured periodically to obtain compensated noise correlation estimates, and to generate and transmit Channel Quality Indicator reports to the cellular communication network based on the compensated noise correlation estimates.

24. The device of claim 12, wherein the device comprises a Wideband Code Division Multiple Access mobile station configured for operation in a Wideband Code Division Multiple Access wireless communication network.

25. A computer readable medium storing a computer program for a wireless communication device comprising:

program instructions to generate a noise correlation estimate for a received signal;

program instructions to calculate an error term corresponding to the noise correlation estimate arising from a receiver frequency error; and

program instructions to obtain a compensated noise correlation estimate by removing the error term from the noise correlation estimate.

26. The computer readable medium of claim 25, wherein the computer program comprises program instructions to generate a signal quality estimate from the compensated noise correlation estimate.

27. The computer readable medium of claim 26, wherein the computer program comprises program instructions to estimate the receiver frequency error used to calculate the error term based on observing symbol phase changes over a defined interval of reference channel symbols received in conjunction with the received signal.

28. The computer readable medium of claim 25, wherein the computer program comprises program instructions to generate propagation channel estimates based on despread reference symbols obtained from a received reference signal, and wherein the program instructions to generate the noise correlation estimate comprise program instructions to generate a noise correlation matrix from the reference symbols and the corresponding propagation channel estimates.

29. The computer readable medium of claim 25, wherein the program instructions to generate the noise correlation estimate comprises program instructions to generate a noise correlation matrix based on a received reference channel signal and corresponding propagation channel estimates.

30. The computer readable medium of claim 29, wherein the program instructions to calculate the error term comprise program instructions to calculate an error matrix based on an estimate of the receiver frequency error and a channel correlation matrix determined from the propagation channel estimates.

31. The computer readable medium of claim 30, wherein the program instructions to obtain the compensated noise correlation estimate comprise program instructions to obtain a compensated noise correlation matrix by subtracting the error matrix from the noise correlation matrix.

32. The computer readable medium of claim 25, wherein the program instructions to generate a noise correlation estimate for a received signal comprise program instructions to generate an initial noise covariance matrix having an error component arising from the receiver frequency error, and wherein the program instructions to obtain a compensated noise correlation estimate by removing the error term from the noise correlation estimate comprise program instructions to subtract an error matrix from the initial noise covariance matrix to obtain a compensated noise covariance matrix.

33. The computer readable medium of claim 32, wherein the program instructions to calculate an error term corresponding to the noise correlation estimate arising from a receiver frequency error comprises program instructions to compute an error matrix based on determining a pilot symbol phase change over a defined interval of pilot symbols received in association with the received signal.

34. The computer readable medium of claim 32, further comprising program instructions to compute a signal quality estimate for the received signal based on the compensated noise covariance matrix.

35. The computer readable medium of claim 32, further comprising program instructions to compute RAKE combining weights for RAKE receiver processing of the received signal based on the compensated noise covariance matrix.

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**BEFORE THE BOARD OF PATENT APPEALS
AND INTERFERENCES**

Application Number: 10/991,878
Filing Date: November 18, 2004
Appellant(s): WALLEN, ANDERS

Daniel P. Homiller
For Appellant

EXAMINER'S ANSWER

This is in response to the appeal brief filed on February 03, 2010 appealing from the Office action mailed on July 31, 2009.

(1) Real Party in Interest

A statement identifying by name the real party in interest is contained in the brief.

(2) Related Appeals and Interferences

The examiner is not aware of any related appeals, interferences, or judicial proceedings which will directly affect or be directly affected by or have a bearing on the Board's decision in the pending appeal.

(3) Status of Claims

The statement of the status of claims contained in the brief is correct.

(4) Status of Amendments After Final

No amendment after final has been filed.

(5) Summary of Claimed Subject Matter

The summary of claimed subject matter contained in the brief is correct.

(6) Grounds of Rejection to be Reviewed on Appeal

The appellant's statement of the grounds of rejection to be reviewed on appeal is correct.

(7) Claims Appendix

The copy of the appealed claims contained in the Appendix to the brief is correct.

(8) Evidence Relied Upon

US 4,477,912	Russell	10-1984
US 7,408,894 B2	Kim et al	08-2008
US 6,714,585 B1	Wang et al	03-2004
US 2005/0069023 A1	Bottomley et al	03-2005
US 6,563,885 B1	Magee et al	05-2003
US 6,470,047 B1	Kleinerman et al	10-2002
US 5,239,591	Ranganath	08-1993
US 5,490,165	Blakeney et al	02-1996
US 6,807,242 B1	Mutoh	10-2004

(9) Grounds of Rejection

The following ground(s) of rejection are applicable to the appealed claims:

Claim Rejections - 35 USC § 103

1. The following is a quotation of 35 U.S.C. 103(a) which forms the basis for all obviousness rejections set forth in this Office action:

> (a) A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negatived by the manner in which the invention was made.

2. Claims 1, 2, 5-8, 12-14, 16, 19, 23, 25, 26 and 29-31 are rejected under 35 U.S.C. 103(a) as being unpatentable over Russell (US 4,477,912).

Consider claims 1, 12 and 25:

Russell discloses a method of improving noise estimation processing in a wireless communication receiver (*see Russell at col. 2, lines 35-43, where Russell describes an invention for data communications between radio transmitters and receivers employing correlation detection techniques; see the abstract, where Russell describes the undesirable signal variations are eliminated from the output of the correlation detection*) comprising:

- generating a correlation estimate for a received signal (*see Russell at Fig. 2 and col. 9, lines 3-38, where Russell describes a received signal is fed to a correlation detector 53*);
- calculating an error term corresponding to the correlation estimate arising from a receiver frequency error (*see Russell at the abstract, col. 2, lines 44-56 and col. 11, lines 40-46, where Russell describes that undesirable signal variations in the output of the correlation detector 53 is detected, which is the effects of the frequency translation error*); and
- obtaining a compensated correlation estimate by removing the error term from the correlation estimate (*see Russell at the abstract, col. 2, lines 44-56 and col. 11, lines 40-46, where Russell describes that undesirable signal variations in the output of the correlation detector 53 caused by a frequency translation error introduced in the transmission and reception of the pseudo random binary code is eliminated by a*

feedback system which detects the effects of the frequency translation error at the output of the correlation detector 53).

Russell discloses the above correlation is pseudo random signal correlation (*see Russell at col. 7, lines 55-67*) instead of noise correlation. The pseudo random signal disclosed by Russell is a pseudo noise signal and it is well known to one of ordinary skill in the art that pseudo noise has the same characteristics as noise. Therefore, it would have been obvious to one of ordinary skill in the art at the time the invention was made to utilizing Russell's invention in the noise correlation.

Consider claims 2, 13, 14 and 26:

Russell discloses the invention of claims 1, 12 and 25 above. Russell discloses calculating a signal-to-interference ratio based on the compensated noise correlation estimate (*see Russell at col. 3, lines 12-19, where Russell describes the minimization of distortion of the pseudo random binary code words such that signal-to-interference ratios are not degraded significantly*).

Consider claim 5:

Russell discloses the invention of claim 1 above. Russell discloses determining signal quality estimates for the received signal based on the compensated noise correlation estimate (*see Russell at col. 14, lines 26-31, where Russell teaches improving the quality of the correlation detector output*).

Consider claims 6 and 29:

Russell discloses the invention of claims 1 and 25 above. Russell discloses generating an initial correlation matrix based on a received reference channel signal and corresponding

propagation channel estimates (*see Russell at col. 8, lines 59-68, where Russell is discussing correlates incoming pseudo random binary code words with similar locally generated reference pseudo random binary code words*).

Consider claims 7 and 30:

Russell discloses the invention of claims 6 and 29 above. Russell discloses calculating an error matrix based on an estimate of the receiver frequency error and a channel correlation matrix determined from the propagation channel estimates (*see Russell at the abstract, col. 2, lines 44-56 and col. 11, lines 40-46, where Russell describes that undesirable signal variations, that is an error matrix, in the output of the correlation detector 53 is detected, which is the effects of the frequency translation error*).

Consider claims 8, 19 and 31:

Russell discloses the invention of claims 7 and 30 above. Russell discloses subtracting the error matrix from the initial noise correlation matrix to obtain a compensated noise correlation matrix (*see Russell at col. 10, lines 2-13, where Russell describes the unlike bits are subtracted from the sum of product of the like bits to produce the correlation between incoming pseudo random binary code word and the locally generated reference pseudo random binary code word*).

Consider claim 16:

Russell discloses the invention of claim 12 above. Russell discloses the receiver circuit includes or is associated with a frequency error estimation circuit configured to estimate the receiver frequency error used to calculate the error term (*see Russell at col. 15, lines 14-18, where Russell describes determining a frequency translation error*).

Consider claim 23:

Russell discloses the invention of claim 12 above. Russell discloses a mobile station configured for operation in a cellular communication network (*see Russell at col. 2, lines 35-43, where Russell describes the invention is for high frequency SSB radio transmitter and receivers which can be used on cellular network*), and wherein the mobile station is configured periodically to obtain compensated noise correlation estimates, and to generate and transmit Channel Quality Indicator reports to the cellular communication network based on the compensated noise correlation estimates (*see Russell at Fig. 4a, 4b and col. 13, lines 3-19, where Russell describes diagrams showing the output from the correlation detector 53*).

3. Claims 3 and 15 are rejected under 35 U.S.C. 103(a) as being unpatentable over Russell (US 4,477,912), as applied to claims 2 and 13 above, and in view of Kim et al (US 7,408,894 B2).

Consider claims 3 and 15:

Russell discloses the invention of claims 2 and 13 above. Russell does not disclose determining a Channel Quality Indicator from the signal-to-interference ratio for transmission to a supporting wireless communication network.

Kim teaches determining a Channel Quality Indicator from a signal-to-interference ratio for transmission to a supporting wireless communication network (*see Kim at col. 5, lines 37-54*).

It would have been obvious to one of ordinary skill in the art at the time the invention was made to modify the invention of Russell, and to determining a Channel Quality Indicator

from the signal-to-interference ratio for transmission to a supporting wireless communication network, as taught by Kim, thus allowing for improving transmission power control, as discussed by Kim (*see Kim at col. 3, lines 17-42*).

4. Claims 4 and 18 are rejected under 35 U.S.C. 103(a) as being unpatentable over Russell (US 4,477,912), as applied to claims 1, 12 and 25 above, and in view of Wang et al (US 6,714,585 B1).

Consider claims 4 and 18:

Russell discloses the invention of claims 1 and 12 above. Russell does not specifically disclose determining RAKE combining weight for a RAKE receiver circuit included in the wireless communication receiver based on the compensated noise correlation estimate.

Wang teaches obtaining RAKE combining weight based on noise correlation estimate (*see Wang at col. 4, lines 29-57 and col. 10, lines 15-47*).

It would have been obvious to one of ordinary skill in the art at the time the invention was made to modify the invention of Russell, and to have a computation of RAKE combining weights based on noise correlation estimate for a RAKE receiver, as taught by Wang, thus allowing improvement in received spread spectrum signals that account for interference, as discussed by Wang (*see col. 3, lines 10-41*).

5. Claims 21 and 28 are rejected under 35 U.S.C. 103(a) as being unpatentable over Russell (US 4,477,912), as applied to claims 12 and 25 above, and in view of Bottomley et al (US 2005/0069023 A1).

Consider claims 21 and 28:

Russell discloses the invention of claims 12 and 25 above. Russell does not disclose a RAKE-type receiver configured to despread a received reference channel signal to obtain reference symbols, and a channel estimation circuit configured to generation propagation channel estimates from the reference symbols, and wherein the noise correlation estimate comprises a noise covariance matrix generated from the reference symbols and the corresponding propagation channel estimates.

Bottomley teaches a RAKE-type receiver configured to despread a received reference channel signal to obtain reference symbols, and a channel estimation circuit configured to generation propagation channel estimates from the reference symbols (*see Bottomley at paragraph 0029, where Bottomley describes that a RAKE processor can be configured to generate estimates of channel coefficient cross-correlations using received pilot symbols, that is reference symbols*), and wherein the noise correlation estimate comprises a noise covariance matrix generated from the reference symbols and the corresponding propagation channel estimates (*see Bottomley at paragraph 0052, where Bottomley describes that the noise covariance is depending on channel estimation error statistics which is calculated from the pilot symbols*).

It would have been obvious to one of ordinary skill in the art at the time the invention was made to modify the invention of Russell, and to have a RAKE-type receiver configured to despread a received reference channel signal to obtain reference symbols, and a channel estimation circuit configured to generation propagation channel estimates from the reference symbols, wherein the noise correlation estimate comprises a noise covariance matrix generated

from the reference symbols and the corresponding propagation channel estimates, as taught by Bottomley, thus allowing for improvement in signal-to-noise ratio of a RAKE receiver, as discussed by Bottomley (*see Bottomley paragraph 0003*).

6. Claims 9, 10, 22, 32 and 34 are rejected under 35 U.S.C. 103(a) as being unpatentable over Russell (US 4,477,912), as applied to claims 1, 12 and 25 above, and in view of Magee et al (US 6,563,885 B1)

Consider claims 9, 22 and 32:

Russell discloses the invention of claims 1, 12 and 25 above. Russell does not disclose generating an initial noise covariance matrix based on a received reference channel signal and corresponding propagation channel estimates generated from the received reference channel signal.

Magee teaches generating an initial noise covariance matrix based on a received reference channel signal and corresponding propagation channel estimates generated from the received reference channel signal (*see col. 8, lines 42-65, where Magee discusses computation performed on the initial noise estimates for each of the antenna signals, thus received reference channel signal, to provide a covariance matrix; see col. 12, lines 22-65 and col. 19, lines 1-30, where Magee teaches updating the initial noise covariance matrix*).

It would have been obvious to one of ordinary skill in the art at the time the invention was made to modify the invention of Russell, and to generate an initial noise covariance matrix based on a received reference channel signal and corresponding propagation channel estimates generated from the received reference channel signal, as taught by Magee, thus allowing for the

phase contribution in the interference be removed, as discussed by Magee (*see Magee at col. 9, lines 45-63*).

Consider claim 10:

Russell in view of Magee discloses the invention of claim 9 above. Russell does not disclose the reference channel signal is a pilot channel signal, and wherein the propagation channel estimates are generated from received pilot symbols.

Magee discloses a pilot channel signal (*see col. 7, lines 12-64, where Magee is discussing a channel estimator configured to provide an indication of the magnitude and phase of the training tone (or pilot tone) of the data signals received at the antennas*), and propagation channel estimates are generated from received pilot symbols (*see col. 4, lines 1-37, where Magee is discussing computing a channel estimate using training tones for use in mitigating the effects of the interference caused by transmission of the received signal*).

It would have been obvious to one of ordinary skill in the art at the time the invention was made to modify the invention of Russell, and to have a pilot channel signal, and wherein the propagation channel estimates are generated from received pilot symbols, as taught by Magee, thus allowing for the phase contribution in the interference be removed, as discussed by Magee (*see Magee at col. 9, lines 45-63*).

Consider claim 34:

Russell in view of Magee discloses the invention of claim 32 above. Russell discloses computing a signal quality estimates for the received signal based on the compensated noise covariance matrix (*see Russell at col. 14, lines 26-31, where Russell teaches improving the quality of the correlation detector output*).

7. Claim 11 is rejected under 35 U.S.C. 103(a) as being unpatentable over Russell (US 4,477,912) in view of Magee et al (US 6,563,885 B1), as applied to claim 10 above, and further in view of Kleinerman et al (US 6,470,047 B1) and Ranganath (US 5,239,591).

Consider claim 11:

Russell in view of Magee discloses the invention of claim 10 above. Russell does not disclose: (1), calculating an error matrix over a defined interval of pilot symbols, and (2), subtracting the error matrix from the initial noise covariance matrix to obtain a compensated noise covariance matrix.

Regarding item (1) above, Kleinerman teaches calculating an error matrix over a defined interval of pilot symbols (*see col. 19, lines 54-67, and col. 20, lines 1-61, where Kleinerman is discussing an error matrix in the noise vector estimation; see col. 11, lines 15-23, where Kleinerman describes the channel estimate is obtained using a know training symbol sequence, therefore a defined interval of pilot symbols*),

It would have been obvious to one of ordinary skill in the art at the time the invention was made to modify the invention of Russell, and to calculate an error matrix over a defined interval of pilot symbols, as taught by Kleinerman, thus allowing for a radio receiver that is capable of reducing interference, as discussed by Kleinerman (*see Kleinerman at col. 4, lines 46-54*).

Regarding item (2) above, Ranganath teaches subtracting an error from a correlation to obtain a compensated correlation (*see Ranganath at Fig. 6C and col. 10, lines 12-43*).

It would have been obvious to one of ordinary skill in the art at the time the invention was made to modify the invention of Russell, and to subtract the error matrix from the initial noise covariance matrix to obtain a compensated noise covariance matrix, as taught by Ranganath, thus allowing for improving the accuracy of the correlation value.

8. Claim 17 is rejected under 35 U.S.C. 103(a) as being unpatentable over Russell (US 4,477,912), as applied to claim 16 above, and in view of Blakeney et al (US 5,490,165).

Consider claim 17:

Russell in view of Ashley discloses the invention of claim 16 above. Russell does not disclose estimating the receiver frequency error based on determining a symbol phase change over a defined interval of pilot symbols in a pilot signal received in association with the received signal.

Blakeney teaches estimating the receiver frequency error based on determining a symbol phase change over a defined interval of pilot symbols in a pilot signal received in association with the received signal (*see Blakeney at col. 9, lines 48-55*).

It would have been obvious to one of ordinary skill in the art at the time the invention was made to modify the invention of Russell, and to estimate the receiver frequency error based on determining a symbol phase change over a defined interval of pilot symbols in a pilot signal received in association with the received signal, as taught by Blakeney, thus allowing for a soft handoff, as discussed by Blakeney (*see Blakeney at col. 5, lines 30-37*).

9. Claim 20 is rejected under 35 U.S.C. 103(a) as being unpatentable over Russell (US 4,477,912), as applied to claim 19 above, and in view of Ranganath (US 5,239,591).

Consider claim 20:

Russell discloses the invention of claim 19 above. Russell discloses calculating the error term as an error matrix based on the receiver frequency error (*see Russell at the abstract*).

Russell does not disclose subtracting the error matrix from the initial noise covariance matrix to obtain a compensated noise covariance matrix.

Ranganath teaches subtracting an error from a correlation to obtain a compensated correlation (*see Ranganath at Fig. 6C and col. 10, lines 12-43*).

It would have been obvious to one of ordinary skill in the art at the time the invention was made to modify the invention of Russell, and to subtract the error matrix from the initial noise covariance matrix to obtain a compensated noise covariance matrix, as taught by Ranganath, thus allowing for improving the accuracy of the correlation value.

10. Claim 24 is rejected under 35 U.S.C. 103(a) as being unpatentable over Russell (US 4,477,912), as applied to claim 12 above, and in view of Mutoh (US 6,807,242 B1).

Consider claim 24:

Russell discloses the invention of claim 12 above. Russell does not disclose a Wideband Code Division Multiple Access mobile station.

Mutoh discloses a Wideband Code Division Multiple Access mobile station configured for operation in a Wideband Code Division Multiple Access wireless communication network (*see Mutoh at col. 1, lines 25-30, where Mutoh teaches W-CDMA*).

It would have been obvious to one of ordinary skill in the art at the time the invention was made to modify the invention of Russell, and to have a Wideband Code Division Multiple Access mobile station, as taught by Mutoh, thus allowing for improved wireless network performance.

11. Claim 33 is rejected under 35 U.S.C. 103(a) as being unpatentable over Russell (US 4,477,912) in view of Magee et al (US 6,563,885 B1), as applied to claim 32 above, and further in view of Blakeney et al (US 5,490,165).

Consider claim 33:

Russell in view of Magee discloses the invention of claim 32 above. Russell does not disclose program instructions to compute an error matrix based on determining a pilot symbol phase change over a defined interval of pilot symbols received in association with the received signal.

Blakeney teaches compute an error based on determining a pilot symbol phase change over a defined interval of pilot symbols received in association with the received signal (*see Blakeney at col. 9, lines 48-55*).

It would have been obvious to one of ordinary skill in the art at the time the invention was made to modify the invention of Russell, and to have program instructions to compute an error matrix based on determining a pilot symbol phase change over a defined interval of pilot symbols received in association with the received signal, as taught by Blakeney, thus allowing for a soft handoff, as discussed by Blakeney (*see Blakeney at col. 5, lines 30-37*).

12. Claim 27 is rejected under 35 U.S.C. 103(a) as being unpatentable over Russell (US 4,477,912) in view of Blakeney et al (US 5,490,165).

Consider claim 27:

Russell discloses the invention of claim 26 above. Russell does not disclose estimating the receiver frequency error used to calculate the error term based on observing symbol phase changes over a defined interval of reference channel symbols received in conjunction with the received signal**.**

Blakeney teaches a frequency error estimation circuit is configured to estimate the receiver frequency error based on determining a symbol phase change over a defined interval of pilot symbols in a pilot signal received in association with the received signal (*see Blakeney at col. 9, lines 48-55*).

It would have been obvious to one of ordinary skill in the art at the time the invention was made to modify the invention of Russell, and to estimate the receiver frequency error used to calculate the error term based on observing symbol phase changes over a defined interval of reference channel symbols received in conjunction with the received signal, as taught by Blakeney, thus allowing for a soft handoff, as discussed by Blakeney (*see Blakeney at col. 5, lines 30-37*).

13. Claim 35 is rejected under 35 U.S.C. 103(a) as being unpatentable over Russell (US 4,477,912) in view of Magee et al (US 6,563,885 B1), as applied to claim 32 above, and further in view of Wang et al (US 6,714,585 B1).

Consider claim 35:

Russell in view of Magee discloses the invention of claim 32 above. Russell does not disclose computing RAKE combining weights for RAKE receiver processing of the received signal based on the compensated noise covariance matrix.

Wang teaches obtaining RAKE combining weight based on noise correlation estimate (*see Wang at col. 4, lines 29-57 and col. 10, lines 15-47*).

It would have been obvious to one of ordinary skill in the art at the time the invention was made to modify the invention of Russell, and to compute RAKE combining weights for RAKE receiver processing of the received signal based on the compensated noise covariance matrix, as taught by Wang, thus allowing improvement in received spread spectrum signals that account for interference, as discussed by Wang (*see col. 3, lines 10-41*).

(10) Response to Argument

A. With respect to claims 1-35:

(1) Applicant's Arguments: "The rejections of independent claims 1, 12, and 25 are without any basis in fact, as Russell has nothing to do with "noise correlation" estimation".

Examiner's Response: The prior art by Russell and the instant application are in the same area of wireless digital communication system, more specifically, they are both directed to improvement of correlation estimation (**see Russell at Fig. 2**). In Russell's invention, a pseudo-random binary code is estimated using a correlation detector. As is well known in the art, pseudo-random binary codes are considered noise. Please check the Reference by Napier (US 5,057,795, Oct. 15, 1991) in which Napier discloses that pseudo-random binary sequence generators have been used as noise sources in commercial instruments for some time (**Napier at**

col. 1, lines 34-40). Russell further discloses that a feedback is applied to offset the undesirable signal variations in the correlation estimation (**see Russell at the Abstract**).

(2) Applicant's Arguments: "In fact, Russell never uses the word 'noise' or any form of the word 'estimate' at all".

Examiner's Response: As discussed above, Russell uses a correlation detector. The output from correlation detection is always an 'estimate' since a correlation returns the closet detection value.

(3) Applicant's Arguments: "Likewise, the Pending Office Action also avoids alleging that Russell discloses the calculation of an error term corresponding to the noise correlation estimate, or that Russell discloses obtaining a compensated noise correlation estimate, based on the error term".

Examiner's Response: Russell discloses in the Abstract the following:

"undesirable signal variations in the output of the correlation detector caused by a frequency translation error introduced in the transmission and reception of the pseudo-random binary code is eliminated by a feedback system which detects the effects of the frequency translation error at the output of the correlation detector and applies a frequency correction signal component to the pseudo-random binary code which offsets the frequency translation error".

It is clear that the 'undesirable signal variations' is an 'error term', and the feedback to offset the 'undesirable signal variations' will compensate for the correlation detection. As stated

by Russell, Russell's invention is for "compensation for frequency translation errors" (**see Russell at col. 2, lines 30-35**).

(4) Applicant's Arguments: "These claims are directed to the calculation of a signal quality, based on a specific quantity, i.e., the compensated noise correlation estimate of the parent claim. Russell merely states that an objective of the receiver techniques disclosed therein is to avoid degrading the signal-to-interference ratio of a received signal. This signal-to-interference ratio is an inherent quality of the received signal. Nothing in Russell suggests that this inherent quality is estimated at all. And nothing in Russell suggests that any signal quality, much less a signal-to-interference ratio, can or should be calculated based on a compensated noise correlation estimate".

Examiner's Response: As is noticed by the Applicant, Russell states that an objective of the receiver techniques disclosed therein is to avoid degrading the signal-to-interference ratio of a received signal. As is clear to one of ordinary skill in the art, one has to get an estimate of the signal-to-interference ratio to be able to tell whether or not the signal-to-interference ratio has degraded.

(5) Applicant's Arguments: "In fact, Russell does not teach or suggest the generation of an initial noise correlation matrix, or any matrix at all".

Examiner's Response: As is seen at col. 8, lines 59-68, Russell is discussing "correlates incoming pseudo random binary code **words** with similar locally generated reference pseudo random binary code **words**". As is known by one of ordinary skill in the art, a matrix is just a

collection of data items, or an array of data items. Therefore, a plurality of the correlation values is equivalent to a correlation matrix.

(6) Applicant's Arguments: "the Pending Office Action's equating of Russell's 'undesirable signal variations' with the claimed 'error matrix' is without basis in Russell or in fact".

Examiner's Response: Russell states in the Abstract that the 'undesirable signal variations' in the output of the correlation detection caused by a frequency translation error is eliminated. As is known by one of ordinary skill in the art, a matrix is just a collection of data items, or an array of data items. Therefore a plurality of undesirable signal variations is equivalent to an error matrix.

(11) Related Proceeding(s) Appendix

No decision rendered by a court or the Board is identified by the examiner in the Related Appeals and Interferences section of this examiner's answer.

For the above reasons, it is believed that the rejections should be sustained.

United States Patent [19]

Russell

[11] **Patent Number: 4,477,912**

[45] **Date of Patent: Oct. 16, 1984**

[54] **CORRELATION DATA COMMUNICATIONS SYSTEM**

[75] Inventor: **James L. Russell,** Germantown, Md.

[73] Assignee: **Arinc Research Corporation,** Annapolis, Md.

[21] Appl. No.: **348,425**

[22] Filed: **Feb. 12, 1982**

[51] **Int. Cl.**[3] **H04K 1/04**

[52] **U.S. Cl.** .... **375/1;** 340/347 DD; 178/22.14; 375/96

[58] **Field of Search** .... 375/1, 2.1, 94, 96, 375/97, 115; 371/49, 55; 178/22.1, 22.13, 22.14, 22.17; 370/18, 19; 331/78; 328/65; 340/347 DD, 351, 352

[56] **References Cited**

U.S. PATENT DOCUMENTS

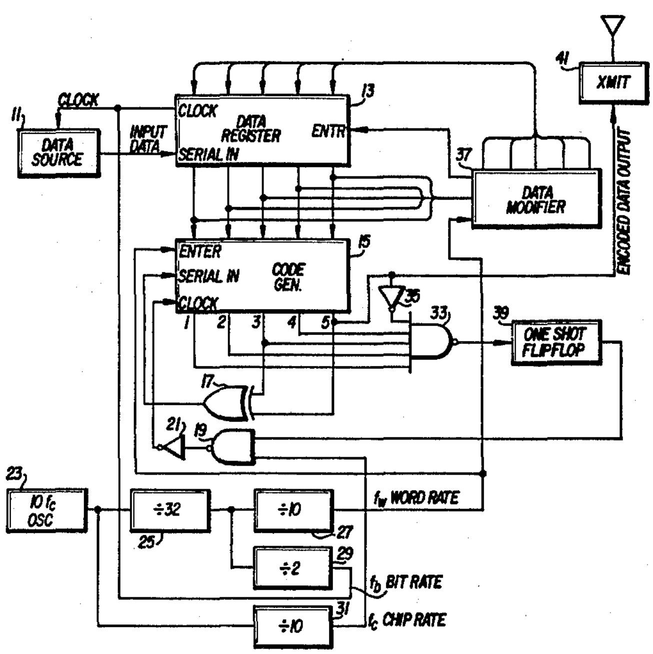
2,894,684	7/1959	Nettleton	371/49
4,052,565	10/1977	Baxter	375/25
4,231,113	10/1980	Blasbalg	375/1

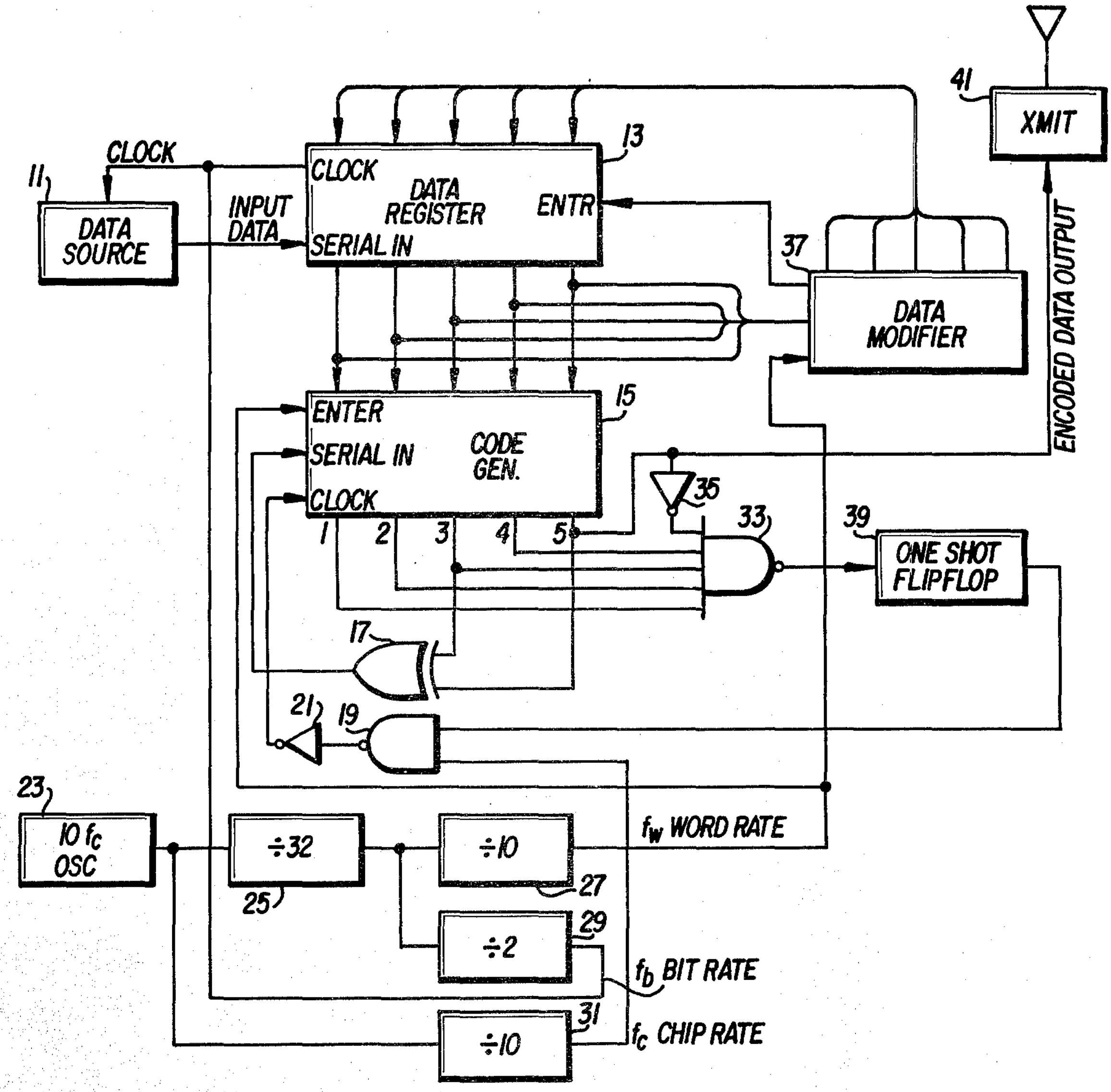
Primary Examiner—Benedict V. Safourek
Attorney, Agent, or Firm—Parkhurst & Oliff

[57] **ABSTRACT**

A digital data communications system employing correlation detection is disclosed as comprising an encoding system which encodes successive k-bit data words from a data source into predetermined start-stop phases of either a 2^k-bit repeating pseudorandom binary code or a 2^k-1 bit repeating pseudorandom binary code and a decoding system which receives the stream of ones and zeros in the pseudorandom binary code from the encoder and reproduces therefrom, using a correlation detector and associated circuitry, a replica of the original k-bit data word from the data source. Undesirable signal variations in the output of the correlation detector caused by a frequency translation error introduced in the transmission and reception of the pseudorandom binary code is eliminated by a feedback system which detects the effects of the frequency translation error at the output of the correlation detector and applies a frequency correction signal component to the pseudorandom binary code which offsets the frequency translation error prior to introduction of the pseudorandom binary code to the correlation detector.

31 Claims, 8 Drawing Figures

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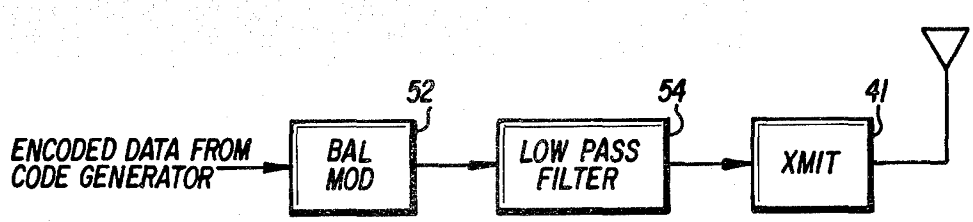
13
CLOCK
DATA REGISTER
ENTR
SERIAL IN
41
XMIT
37
DATA MODIFIER
ENCODED DATA OUTPUT
15
ENTER
SERIAL IN
CODE GEN.
CLOCK
1
2
3
4
5
35
33
39
ONE SHOT FLIPFLOP
17
21
19
23
10 f_c OSC
÷32
25
÷10
27
f_w WORD RATE
÷2
29
f_b BIT RATE
÷10
31
f_c CHIP RATE

FIG. 1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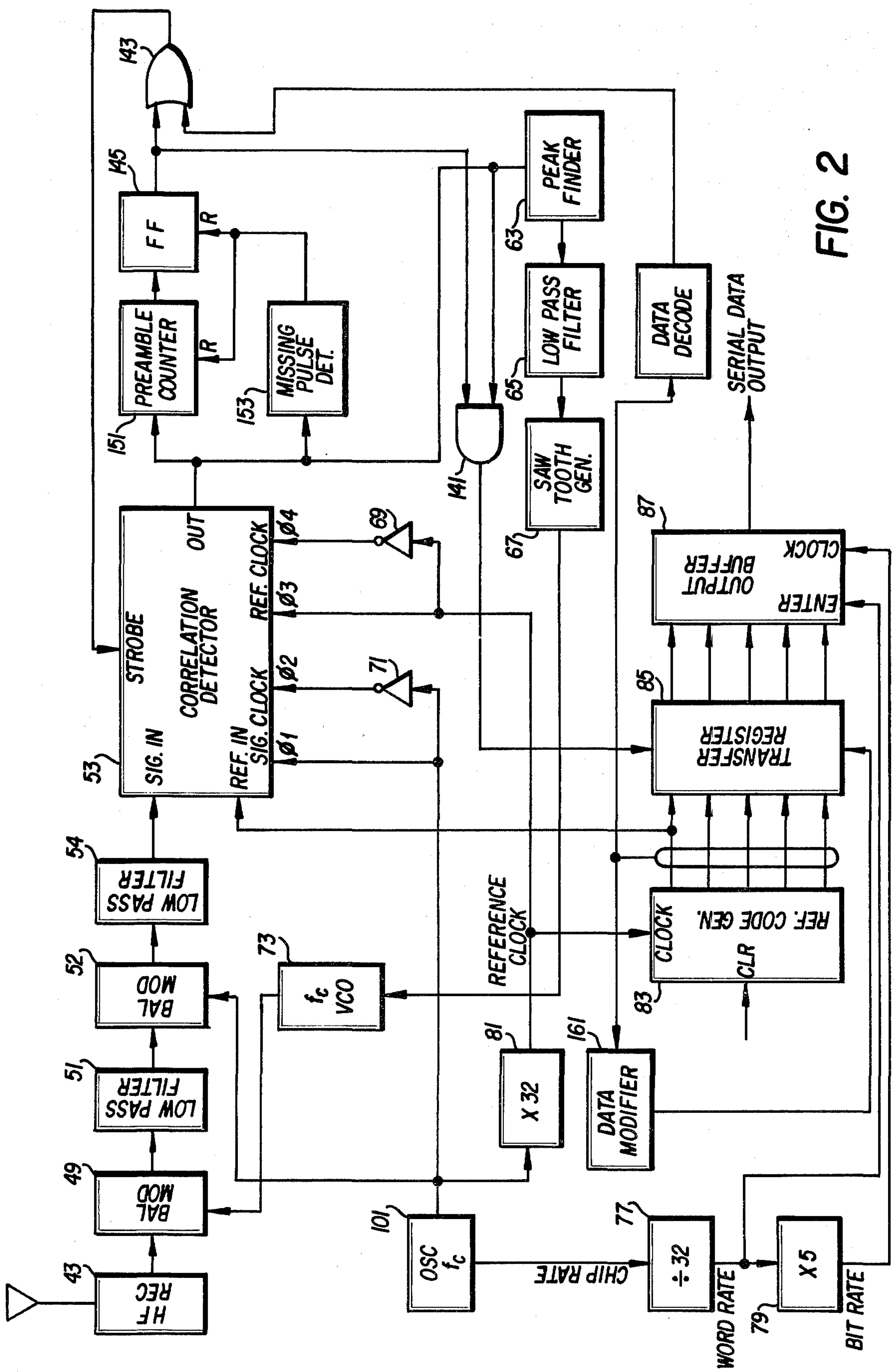
52
BAL MOD
54
LOW PASS FILTER
41
XMIT

FIG. 3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LOW PASS FILTER
CORRELATION DETECTOR
SIG. IN
STROBE
OUT
REF. IN
SIG. CLOCK
REF. CLOCK
PREAMBLE COUNTER
MISSING PULSE DET.
F F
PEAK FINDER
LOW PASS FILTER
SAW TOOTH GEN.
DATA DECODE
SERIAL DATA OUTPUT
f_c VCO
REFERENCE CLOCK
X 32
DATA MODIFIER
REF. CODE GEN.
CLOCK
CLR
TRANSFER REGISTER
OUTPUT BUFFER
ENTER
CLOCK
OSC f_c
CHIP RATE
÷ 32
X 5
WORD RATE
BIT RATE

FIG. 2

FIG. 4A

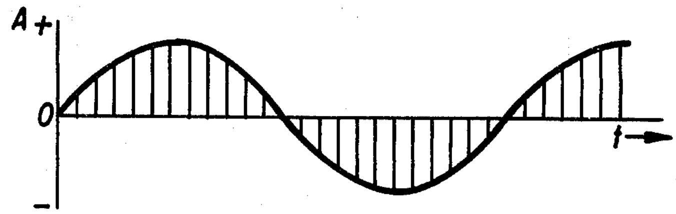
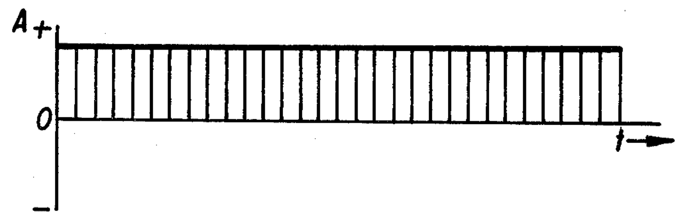


FIG. 4B



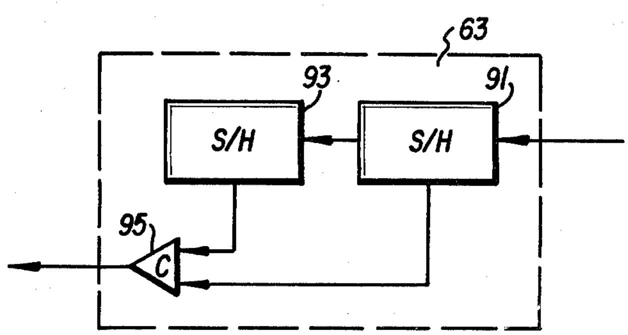
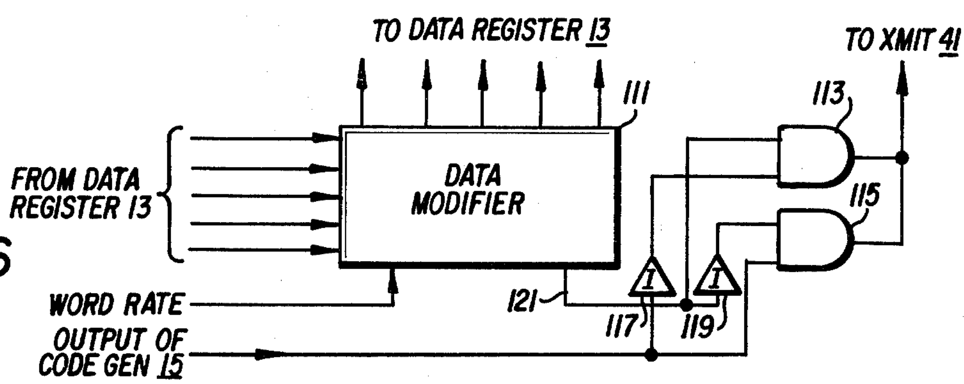


FIG. 5

FIG. 6



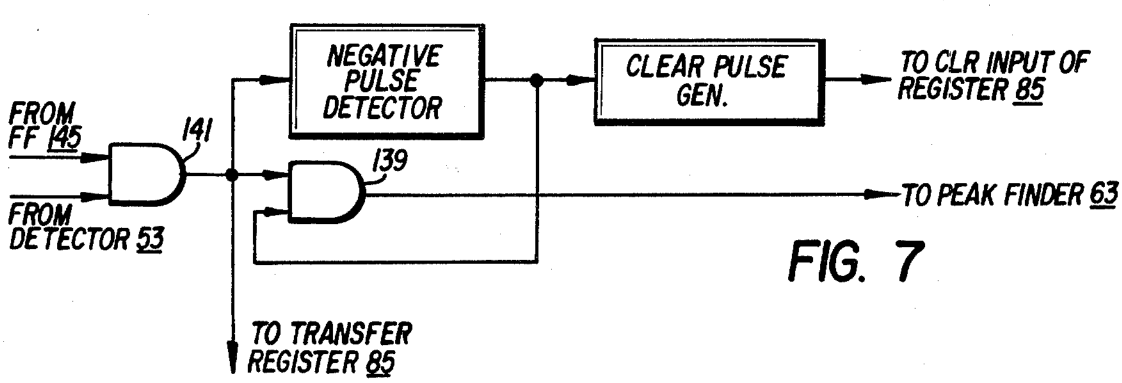


FIG. 7

CORRELATION DATA COMMUNICATIONS SYSTEM

FIELD OF THE INVENTION

The present invention relates to digital data communications systems and, more particularly, to such systems which employ correlation detection to determine the identity of an incoming encoded digital code word.

BACKGROUND OF THE INVENTION

The use of correlation techniques in a data communications system decoding system to identify an incoming digital code word is well known. In a correlation decoding system a correlation detector is provided which matches an incoming digital code word on a bit-for-bit basis with a plurality of locally generated reference code words. When a substantial match with one of the reference code words is found, the correlator indicates this fact by an output signal, the amplitude of which represents the degree of bit-for-bit matching, and the reference code word with which the incoming digital code word is then being compared is identified as the received code word.

If a communication system employing a correlation detector in the decoding system uses Single Side Band (SSB) modulation for transmission and reception, Doppler shifts in the medium and carrier reinsertion errors in the receiver will shift each frequency in the demodulated output signal by some translation error which is the same for all output frequencies at the demodulator at any given instant, but which can vary with time due to changes in relative velocities of the transmitter and receiver and to variations in frequency standards in the transmitter and receiver. For SSB receivers and transmitters in the high frequency (HF) band (2 to 30 MHz), frequency translation errors in the demodulator output of up to ± 100 Hz are common.

When a frequency translation error occurs, it has been found that the output signal of the correlation detector rotates in phase at the translation error frequency providing the envelope of the output signal of the correlation detector with an amplitude which is sinusoidal, varying at the translation frequency. With very low (or even zero) translation errors, if the phase of the correlation detector output is near a sinusoidal null of the amplitude variation, the correlation detector output will be low or zero and will remain so until the phase rotates away from the null. Such a low output of the correlation detector may cause the decoding system to fail to properly recognize a match between an incoming digital code word and one of the internally generated reference code words.

It is also often desirable to retrofit a data communications system to an existing operational radio transmitter and receiver system to avoid the expense of designing an entirely new transmission and reception system for data transmission. If a data communications system is retrofit to High-Frequency (HF) radio transmitters and receivers designed for Single Side Band (SSB) voice transmissions, a problem exists in that the limited audio band pass (usually 300 to 2500 Hz) of the transmitters and receivers prohibits use of wide-band spread-spectrum techniques commonly employed at UHF and microwave frequencies to improve code transmission reliability. At the same time the many forms of signal degradation associated with HF transmitters and receivers, such as fading, high interference, multipath propogation, etc. places demands on the data communications system which are not easily satisfied by simple frequency-shift keying or other conventional digital transmission techniques. To successfully permit utilization of in place High-Frequency SSB radio transmitters and receivers for data communications, the data communications system must:

a. provide a unique wave form in space which is highly unlikely to be duplicated by probable sources of interference or to be modified by such interference to produce undetected output errors;

b. provide a high degree of error detection and correction;

c. provide the ability to accept the waveform to which a receiver is synchronized while rejecting interference (either from other transmitters or from multipath propagation of the desired transmission) from similar waveforms not precisely in synchronism;

d. permit as high a communications data rate as possible within the transmitter/receiver bandpass limitations;

e. be implemented through addition of external encoder and decoder circuitry without modification of existing transmitters and/or receivers and without access to transmitter carrier frequency control circuits to achieve phase or frequency modulation nor to receiver RF or IF circuitry as would be required for demodulation of frequency or phase modulation or conventional correction of SSB translation errors; and

f. provide for synchronization of the demodulator to received signals and compensation for frequency translation errors over the same range of signal-to-interference ratios as required for signal processing after synchronization is achieved.

SUMMARY OF THE INVENTION

The present invention has been devised to eliminate the frequency translation problem in data communications systems employing correlation detection techniques in the decoder and to provide a reliable and accurate data communications system which can be easily retrofit to existing High Frequency SSB radio transmitters and receivers.

Accordingly, one object of the invention is the provision of a digital data communications system wherein the effects of frequency translation errors induced during transmission or reception of a digital code word are eliminated at the output of the decoding system correlation detector thereby improving the overall reliability of the decoding operation. This object is achieved by providing a feedback system which detects the effects of a frequency translation error at the output of the correlation detector and applies a frequency correction signal component to received digital code words which offsets the frequency translation error at the input to the correlation detector.

An additional object of the invention is the provision of a data communications system which permits use of unmodified currently operational High-Frequency (HF) radio transmitters and receivers designed for single side band (SSB) voice transmissions to provide high-quality digital data communications and which satisfies the transmission and reception requirements noted earlier. This object of the invention is achieved through a data communications system, employing an encoding and decoding system, which uses: (1) an encoding system which generates pseudorandom binary code words as start-stop phases of a repeating pseudorandom code

for transmission on which data to be transmitted is impressed by cyclic code shift keying (CCSK), (2) a decoding system which employs correlation detection of received baseband pseudorandom binary code words, and (3) feedback from the correlation detector output through a feedback control loop which eliminates the above-noted frequency translation errors from the received pseudorandom binary code words and permits the decoding system output to be an undistorted representation of the data provided as input to the encoding system.

A further object of the invention is the minimization of distortion of the pseudorandom binary code words caused by passage through the limited bandpass of existing receivers and transmitters by selection of a code for which truncation of the code's frequency spectrum below 300 Hz and above 2500 Hz does not significantly degrade signal-to-interference ratios, nor unacceptably degrade the correlation function of the codeword.

A further object of the invention is the provision of a method for CCSK encoding of pseudorandom binary code words which permits decoding by simple and economical circuitry without the need for microprocessors and look up tables, or other more complex methods conventionally used for CCSK decoding.

An additional object of the invention is the provision of a unique encoding system for generating pseudorandom binary code words having an overall D.C. balance (equal number of ones and zeros) which may be used to advantage in a data communications system.

These and other objects and advantages of the invention will be readily understood from the following detailed description of the invention which is presented in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 illustrated a unique digital encoding system which may be used in the data communications system of the invention;

FIG. 2 illustrates a decoding system which may be used in the data communications system of invention;

FIG. 3 illustrates a modification to the encoding system shown in FIG. 1;

FIG. 4*a* and 4*b* respectively illustrate the envelope of the output of a correlation detector used in the decoding system, with and without aberrations caused by a frequency translation error;

FIG. 5 illustrates a representative peak finding circuit which can be used in the FIG. 2 decoding system;

FIG. 6 illustrates another modification to the encoding system shown in FIG. 1; and

FIG. 7 illustrates a modification to the decoding system illustrated in FIG. 2.

DETAILED DESCRIPTION OF THE INVENTION

The data communications system of the invention is particularly designed to be incorporated into existing transmitting and receiving systems which have a voice data channel and for the purpose of exemplary description the invention will be described for use in a SSB (single side band) High Frequency voice communications system. However, it should be appreciated that the data communications system of the invention can be used in other transmission/reception systems as well, and that the encoding system of the invention may be used with or without the decoding system of the invention and vice versa.

One exemplary encoding system which may be used in the invention is illustrated in FIG. 1. In this system source digital code words having k bits are transmitted as digital code words having 2^k bits, 2^k-1 bits being generated by a pseudorandom code generator **15**, and an additional single bit being added to the output of the pseudorandom code generator to form an even number of bits for transmission. Thus, for example, if a five bit digital source code word is input to the encoding system, the output thereof would be 32 (2^5) chips (bits) in length.

Referring to FIG. **1**, a data source **11** supplying a serial stream of digital code is clocked by the output of a frequency divider **29** which applies a clocking signal at a predetermined bit rate f_b. The clocking signal is also fed as a clocking input to a data register **13** which receives at a serial input thereto the output from data source **11**. Data register **13** is of the type which may receive data into the various register positions either by the serial input connected to the output of the data source **11** or by parallel input which is connected to the output of a data modifier **37**, which is described more fully below. The data register contains a number of bit positions corresponding to the number of bits from data source **11** to be encoded on an output pseudorandom binary code word, e.g. 5 for the example given above. After the selected number of data bits from data source **11** have been loaded into data register **13** its contents are transferred in parallel to a pseudorandom code generator **15** by an ENTER signal (word rate clock signal fw) applied to code generator **15** by frequency divider **27**. Pseudorandom code generator **15** is a well known device which generates at an output, taken, for example, at register stage **5**, a pseudorandom binary code word which is 2^k-1 bits long where k is the number of register stages (which correspond to the k bits of a digital code word to be encoded). The number of possible pseudorandom binary code words which can be generated by code generator **15** is 2^k-1 and each is a different start-stop phase of a repeating 2^k-1 bit pseudorandom code pattern. The code generator **15** is essentially a shift register which continually cycles an input code word thereto through the register with register stages **3** and **5** being summed by an exclusive OR circuit **3** and fed back as a serial input to the code generator **15**. A clock signal supplied to the clock terminal of the pseudorandom code generator **15** advances the serial data through the code generator in cyclic fashion. The clock signal is supplied by an inverter **21** which receives a clocking signal through NAND gate **19** from the output of frequency divider **31** which supplies a clocking signal at chipping rate f_c. Thus, the serial data stream at the output of the pseudorandom code generator **15** (bit position **5**) has a chipping rate of f_c. The first five bits of the pseudorandom binary code word at the output of code generator **15** correspond to the five bits originally loaded into code generator **15**.

After generating a pseudorandom binary code word corresponding to an input digital code word, pseudorandom code generator **15** is reloaded with a new incoming digital code word by the output of frequency divider **27** which applies a word rate clocking signal f_w to the ENTER input of pseudorandom code generator **15**.

As discussed above, a pseudorandom coded output signal having 2^k bits is generated by the encoding system. However, a characteristic of pseudorandom code generator **15** is that 2^k-1 bits are generated. Accord-

ingly, an additional bit is generated and added to the output of pseudorandom code generator **15**. To accomplish this, an NAND gate **33** is connected to the output stages of code generator **15** to determine when a predetermined code condition exists therein. For example, NAND gate **33** may be arranged to detect the state "11110". Upon detection of this state, an output signal from NAND gate **33** causes a one-shot flip flop **39** to generate a pulse signal which inhibits the clocking signal output of NAND gate **19** so that no clocking signal is applied at the clock input to pseudorandom code generator **15** for the time duration of the one-shot flip-flop **39**. The pulse from the one-shot flip-flop is sufficient to prevent one clock pulse from the output of frequency divider **31** from being applied through an NAND **19** and inverter **21** to the clocking input of pseudorandom code generator **15**. Accordingly, whatever bit code ("0" for the code "11110") is then in register stage **5** of the pseudorandom code generator **15** is held for an additional clock signal. When the output pulse from one-shot flip-flop **39** disappears NAND gate **19** is reenabled and clock signals from the output of the divider **31** are again supplied to the clock input of the code generator. Thus, for each n-bit digital code word inputted to code generator **15** from the data register **13**, a 2^k digital code word is generated at the output thereof.

The output of the pseudorandom code generator **15** is supplied to a transmitter **41** which may be a conventional RF transmitter using any suitable type of modulation. As noted, a SSB HF transmitter is particularly suitable.

The word rate f_w, bit rate f_b, and chip rate f_c clocking signals are respectively provided by dividers **27**, **29** and **31** which are run off oscillator **23** operating at a frequency of 10 f_c. Divide-by-ten divider **27** and divide-by-two divider **29** receive the output of oscillator **23** through a divide-by-thirty-two frequency divider **25**, while divide-by-ten frequency divider **31** directly receives the output of oscillator **23**.

As well known, when a pseudorandom code generator is loaded with an all zero code word, e.g. "00000" for a 5 bit system, its output will be a stream of all zeros and it will lock in this state. To eliminate the possibility of an "all zero" code word being loaded into the code generator **15**, data modifier **37** continuously monitors the output of data register **13** and whenever a prohibited digital code word is entered therein, for example, all zeros, the data modifier **37** substitutes a different code word into the data register **13**. The data modifier **37** receives the word rate f_w output from divider **27** and checks every digital code word in data register **13** just before its being loaded into pseudorandom code generator **15** so the forbidden code never is loaded in the code generator. When a forbidden code word is detected the data modifier **37** substitutes a different digital code word into register **13** and supplies a gating signal to data register **13** which allows the data register to accept, by parallel input, the output of data modifier **37**.

Data modifier **37** may also be used to prevent any other incoming digital code words from being fed to random code generator **15**. For example, the digital code word "11111" can be converted to the sequence "01111" by data modifier **37** in order to simplify decoder circuitry (of if the pseudorandom code generator is using inverted logic wherein "11111" would be the prohibited sequence).

It should be noted that the addition of a chip (added bit) to a conventional maximal length code word of length 2^k-1 to produce a 2^k-chip word is not required for CCSK encoding and, in fact, degrades to some extent, the desirable correlation characteristics of the 2^k-1 chip binary code word produced by code generator **15**. However, the added chip permits one to attain an additional pseudorandom binary code word for encoding a forbidden n-bit data word (e.g. all zero). Another way to encode a "forbidden" all-zero (or all-one for code generators with inverted logic) data sequence is to generate in the encoding system any selected one of the other 2^k-1 sequences, but with the code inverted (all zeros changed to ones and all ones to zeros). The decoding system correlation decoder can sense this inversion and substitute the forbidden sequence for the inverted word while, at the same time, inhibiting circuits (such as the detranslation feedback loop described below) which would be adversely affected by the inversion. This alternative encoding technique is illustrated in FIG. **6**.

As shown in FIG. **6**, a data modifier **111** monitors the parallel output from data register **13** for a prohibited code word and substitutes a permitted code word into register **13** as described earlier. In addition, the data modifier generates a control signal which enables a gate **113** and disables a gate **115** through inverter **119**. Gate **113** receives at another input an inverted version of the output of code generator **15**, while gate **115** receives at another input the non-inverted output of code generator **15**. In this arrangement when data modifier **111** detects the presence of a prohibited bit pattern in data register **13** it loads a different, permitted code word therein and supplies a control signal on line **121** which disables gate **115** and enables gate **113** to thereby allow the output of code generator **15** to be inverted by inverter **117** prior to its being fed to transmitter **41**. The inverted pseudorandom binary code word can then be detected in a system decoder and converted to the proper bit patterns.

In the process of generating the 2^k bit pseudorandom binary code word which is applied to transmitter **41**, the encoding system is arranged so that the added bit, which occurs by holding the code generator **15** in a predetermined output position for one clock pulse by NAND gate **33** and one-shot flip-flop **39**, can be a bit value which obtains a balance in the overall number of ones and zeros in the 2^k bit encoded output. In the arrangement shown, this balancing occurs by the addition of a "0" to the 31 (2^k-1) bits generated by the output of the pseudorandom code generator **15** when operating normally. This additional "0" is thus generated by sensing a bit pattern in the code generator **15** which has "0" in the bit **5** stage. One such convenient bit pattern is "11110" as described above. However, it should be clear that the additional zero could be generated at other points in the output of the pseudorandom code generator **15** to provide an added "0" to balance the overall number of ones and zeros in the transmitted pseudorandom binary code word. Moreover, if pseudorandom code generator **15** produces one more "0"'s than "1"'s in its output (as would occur, for example, with inverted logic), then the added bit would be a "1".

The balancing of the overall number of ones and zeros in the generated 2^k bit pseudorandom binary code word has the advantage of providing a DC balance to the overall signal which makes for a simpler design of decoding circuitry. Table I illustrates an exemplary pseudorandom coding (2^k) obtained at the output of code generator **15** for the various states of a 5-bit input

data word. The asterisks denote zeros added in the manner described above.

TABLE I

	DATA	31 BIT CODE -- ASTERISKS ARE 0's ADDED TO MAKE 32 CHIPS
1	0 0 0 0 1	0 0 0 0 1 0 0 1 0 1 1 0 0 0* 1 1 1 1 1 0 0 0 1 1 0 1 1 1 0 1 0 1
2	0 0 0 1 0	0 0 0 1 0 0 1 0 1 1 0 0 0* 1 1 1 1 1 0 0 0 1 1 0 1 1 1 0 1 0 1 0
3	0 0 0 1 1	0 0 0 1 1 0 1 1 1 0 1 0 1 0 0 0 0 1 0 0 1 0 1 1 0 0 0* 1 1 1 1 1
4	0 0 1 0 0	0 0 1 0 0 1 0 1 1 0 0 0* 1 1 1 1 1 0 0 0 1 1 0 1 1 1 0 1 0 1 0 0
5	0 0 1 0 1	0 0 1 0 1 1 0 0 0* 1 1 1 1 1 0 0 0 1 1 0 1 1 1 0 1 0 1 0 0 0 0 1
6	0 0 1 1 0	0 0 1 1 0 1 1 1 0 1 0 1 0 0 0 0 1 0 0 1 0 1 1 0 0 0* 1 1 1 1 1 0
7	0 0 1 1 1	0 0 0* 1 1 1 1 1 0 0 0 1 1 0 1 1 1 0 1 0 1 0 0 0 0 1 0 0 1 0 1 1
8	0 1 0 0 0	0 1 0 0 0 0 1 0 0 1 0 1 1 0 0 0* 1 1 1 1 1 0 0 0 1 1 0 1 1 1 0 1
9	0 1 0 0 1	0 1 0 0 1 0 1 1 0 0 0* 1 1 1 1 1 0 0 0 1 1 0 1 1 1 0 1 0 1 0 0 0
10	0 1 0 1 0	0 1 0 1 0 0 0 0 1 0 0 1 0 1 1 0 0 0* 1 1 1 1 1 0 0 0 1 1 0 1 1 1
11	0 1 0 1 1	0 1 0 1 1 0 0 0* 1 1 1 1 1 0 0 0 1 1 0 1 1 1 0 1 0 1 0 0 0 0 1 0
12	0 1 1 0 0	0 1 1 0 0 0* 1 1 1 1 1 0 0 0 1 1 0 1 1 1 0 1 0 1 0 0 0 0 1 0 0 1
13	0 1 1 0 1	0 1 1 0 1 1 1 0 1 0 1 0 0 0 0 1 0 0 1 0 1 1 0 0 0* 1 1 1 1 1 0 0
14	0 1 1 1 0	0 1 1 1 0 1 0 1 0 0 0 0 1 0 0 1 0 1 1 0 0 0* 1 1 1 1 1 0 0 0 1 1
15	0 1 1 1 1	0 0* 1 1 1 1 1 0 0 0 1 1 0 1 1 1 0 1 0 1 0 0 0 0 1 0 0 1 0 1 1 0
16	1 0 0 0 0	1 0 0 0 0 1 0 0 1 0 1 1 0 0 0* 1 1 1 1 1 0 0 0 1 1 0 1 1 1 0 1 0
17	1 0 0 0 1	1 0 0 0 1 1 0 1 1 1 0 1 0 1 0 0 0 0 1 0 0 1 0 1 1 0 0 0* 1 1 1 1
18	1 0 0 1 0	1 0 0 1 0 1 1 0 0 0* 1 1 1 1 1 0 0 0 1 1 0 1 1 1 0 1 0 1 0 0 0 0
19	1 0 0 1 1	1 0 0 0* 1 1 1 1 1 0 0 0 1 1 0 1 1 1 0 1 0 1 0 0 0 0 1 0 0 1 0 1
20	1 0 1 0 0	1 0 1 0 0 0 0 1 0 0 1 0 1 1 0 0 0* 1 1 1 1 1 0 0 0 1 1 0 1 1 1 0
21	1 0 1 0 1	1 0 1 0 1 0 0 0 0 1 0 0 1 0 1 1 0 0 0* 1 1 1 1 1 0 0 0 1 1 0 1 1
22	1 0 1 1 0	1 0 1 1 0 0 0* 1 1 1 1 1 0 0 0 1 1 0 1 1 1 0 1 0 1 0 0 0 0 1 0 0
23	1 0 1 1 1	1 0 1 1 1 0 1 0 1 0 0 0 0 1 0 0 1 0 1 1 0 0 0* 1 1 1 1 1 0 0 0 1
24	1 1 0 0 0	1 1 0 0 0 1 1 0 1 1 1 0 1 0 1 0 0 0 0 1 0 0 1 0 1 1 0 0 0* 1 1 1
25	1 1 0 0 1	1 1 0 0 0* 1 1 1 1 1 0 0 0 1 1 0 1 1 1 0 1 0 1 0 0 0 0 1 0 0 1 0
26	1 1 0 1 0	1 1 0 1 0 1 0 0 0 0 1 0 0 1 0 1 1 0 0 0* 1 1 1 1 1 0 0 0 1 1 0 1
27	1 1 0 1 1	1 1 0 1 1 1 0 1 0 1 0 0 0 0 1 0 0 1 0 1 1 0 0 0* 1 1 1 1 1 0 0 0
28	1 1 1 0 0	1 1 1 0 0 0 1 1 0 1 1 1 0 1 0 1 0 0 0 0 1 0 0 1 0 1 1 0 0 0* 1 1
29	1 1 1 0 1	1 1 1 0 1 0 1 0 0 0 0 1 0 0 1 0 1 1 0 0 0* 1 1 1 1 1 0 0 0 1 1 0
30	1 1 1 1 0	1 1 1 1 0 0 0 1 1 0 1 1 1 0 1 0 1 0 0 0 0 1 0 0 1 0 1 1 0 0 0* 1
31	1 1 1 1 1	0* 1 1 1 1 1 0 0 0 1 1 0 1 1 1 0 1 0 1 0 0 0 0 1 0 0 1 0 1 1 0 0
32	0 0 0 0 0	1 1 1 1 1 0 0 0 1 1 0 1 1 1 0 1 0 1 0 0 0 0 1 0 0 1 0 1 1 0 0 0*

As evident from the above Table, each of the pseudorandom binary code words generated at the output of code generator **15** represents a different start-stop phase of an endlessly repeating pseudorandom n-bit pattern, where $n=2^k-1$ and k and n are integers.

Although the encoding system of FIG. **1** generates a preferred 2^k bit pseudorandom code from a k-bit data code word, it can also be used to generate a 2^k-1 bit pseudorandom binary code (Table I without the added zeros) by the elimination of inverter **35**, gate **33**, one shot flip-flop **39**, gate **19** and inverter **21** and directly connecting the output of divider **31** to the clock input of code generator **15**. These changes will enable code generator **15** to operate as a conventional pseudorandom code generator and there will be no addition of a bit to the output of code generator **15** as described earlier. The data modifier circuit shown in FIG. **6** will work with the encoding system configured as just described to produce a 2^k-1 pseudorandom code output in which each of the binary code words generated at the output of code generator **15** represents a different start-stop phase of a repeating n-bit pattern where $n=2^k-1$.

The data communications system of the invention employs correlation detection in the decoding system to reproduce the input data words to register **13** from the transmitted and received pseudorandom binary code.

A characteristic of decoding systems employing correlation detection for identifying incoming digital data, such as the pseudorandom binary code generated by the encoding system of FIG. **1**, is that the pulsed output of the correlation detector, which occurs whenever a substantial match is found between an incoming pseudorandom binary code word and one of a plurality of locally generated reference pseudorandom binary code words, rotates in phase at the frequency of any frequency translation error in single side band transmission systems with which the data communications system may be used. Such errors can be caused by Doppler shifts in the transmitting medium and carrier reinsertion errors in the receiver demodulator. This results in the correlation detector output signal envelope having a sinusoidal amplitude component impressed thereon due to the frequency translation error (FIG. **4a**). The translation error shifts each frequency of the demodulator output by some translation error which is the same for all demodulated output frequencies at any given instant, but which varies with time due to changes in relative velocities of the transmitter and receiver and to variations in frequency standards in the transmitter and receiver. As noted earlier, for SSB transmitters and receivers in the high frequency (HF) band (2–30 Mhz) translation errors of up to ±100 hz are common.

The frequency translation error, which occurs as amplitude and phase variations in the output waveform of the correlation detector, may result in a correlation detector output signal being "missed" in the decoding system because it may occur at a point near a sinusoidal null in the output envelope of the correlation detector or because it has an inverted polarity. To eliminate this problem, the decoding system of the invention, as illustrated in FIG. **2**, includes a detranslation circuit which eliminates the sinusoidal variations in the output of the correlation detector.

Before describing FIG. **2** in detail, it should be pointed out that the decoding system shown therein correlates incoming pseudorandom binary code words with similar locally generated reference pseudorandom binary code words. However, it should be understood that the decoding system of the invention can be used with any type of digital coding and that pseudorandom coding is not at all necessary. However, for the purpose of simplifying subsequent description, the pseudorandom binary code words as generated by the encoding

system of FIG. 1 will assumed as being received at the input to the decoding system of FIG. 2.

Referring to FIG. 2, a High Frequency single side-band, receiver 43 receives and demodulates a transmitted signal containing a stream of pseudorandom binary code words. In normal operation, this signal would then be fed to a correlation detector circuit which would compare the arriving pseudorandom binary code words successively with each one of a plurality of locally generated reference pseudorandom code words, the correlator detector signaling a match when found. In the decoding system of FIG. 2, the incoming demodulated pseudorandum binary code words are fed to a balanced modulator 49 where the pseudorandom binary code words modulate a first local carrier at the output of a voltage control oscillator 73. The output from balanced modulator passes through a low pass filter 51 which removes a higher frequency product of the modulation process. The resulting single side band at the output of filter 51 is demodulated by using it to modulate a second local carrier whose frequency is fixed at the approximate center frequency of the voltage controlled oscillator 73 supplying the first local carrier. The second local carrier is supplied by oscillator 101. The upper sideband of the resulting sideband pair is removed by filter 54 leaving a lower side band which is the same as the received signal except that an additional translation error, relative to the received signal, equal to the difference in frequency between the first and second local carrier frequencies has been introduced. The output of low pass filter 54 is applied as an input to correlation detector 53. A feedback loop, described in further detail below, is used to adjust the voltage controlled oscillator 73 so that this translation error is equal and opposite to that present in the received signal and the single sideband resulting from the second modulation is the originally transmitted pseudorandom binary code without translation error.

The center frequency of the voltage controlled oscillator 73 is selected to facilitate removal of one of the modulation side bands by filter 51 and may be, as in the embodiment here discussed and illustrated in FIG. 2, the chipping frequency fc selected for the system. The control range of the voltage controlled oscillator 73 is made wide enough to permit the output frequency to be varied over a range equal to the expected range of the translation error.

Correlation detector 53 may be a standard integrated circuit device, for example, a Reticon R5403. The correlator contains (for a 32 chip code word) two 32-chip "bucket brigade" delay lines. Incoming pseudorandom binary code words are shifted through one of the delay lines by two phase clock signals ϕ_1 and ϕ_2. The other delay line serially receives the locally generated reference pseudorandom binary code words which are shifted in by clock signals ϕ_3 and ϕ_4. A multiplier circuit is provided between each cell of the delay line for the incoming pseudorandom binary code words and a like numbered cell for incoming pseudorandom reference binary code words. A strobe signal to the STROBE input of the correlation detector causes the signals in the delay line cells to be transferred to the multiplier circuit where they are multiplied and the resulting products summed. When the STROBE input is held in a predetermined logic "1" state the contents of the delay line cells will be repeatedly supplied to the multiplier circuit for multiplication. The products of the multiplier circuit are summed into the correlation detector output to provide a continuous summation of the products of each chip. When a reference and incoming pseudorandom code word are alike, all 32 products are positive and add to produce an output pulse 32 times as large in amplitude as a signal due to the multiplication of a single chip. When some chips are alike and some are unlike, the negative products formed by unlike chips are subtracted from the sum of products of the like chips and provide an amplitude at the output of the correlator which is proportional to the degree of match found between the incoming pseudorandom binary code word and a locally generated reference pseudorandom binary code word.

The incoming digital code word is advanced through the correlator by the output of oscillator 101 at the chipping frequency f_c which is supplied to the first clock ϕ_1 input to the correlator 53 and by an inverted signal applied through inverter 73 to the second clock ϕ_2 input to correlator 53.

The reference code words, generated by reference code generator 83, are advanced through correlator detector 53 by two phase clock signals ϕ_3 and ϕ_4 at rate of $32 \times f_c$ formed by a multiplier 81 which multiplies the output f_c of oscillator 101. Because of the 32 to 1 frequency ratio between the incoming pseudorandom binary code word and reference pseudorandom binary code words which are clocked into the correlator 53, all 32 possible reference codes are stepped through the reference delay line between successive clock cycles which control the shifting of the incoming digital code words through correlator detector 53.

Code generator 83 generates a continuously repeating code identical to the basic code generated at the output of the encoding system (FIG. 1). Since the number of cells in the correlator detector is same as the number of chips in the code, the five chips in the reference code generator are always the first five chips of the word in the correlator. Thus, when a match is found between an arrriving digital code word and a locally generated reference code word by correlator detector 53 the output thereof sets a transfer register 85 to the same five bits as exist in the reference code generator 83. This data, which is a replica of the k-bit digital code word originally loaded in data register 13, is then transferred to output buffer 87 at the start of the next word interval as determined by frequency divider 77, where it is serially read out at a bit rate determined by frequency multiplier 79 which multiplies by five the output of frequency divider 77.

At the initiation of a code transmission from the encoding system (FIG. 1) a preamble pseudorandom binary code word is repeatedly generated in a predetermined number of times by repeatedly supplying a predetermined k-bit data word to data register 13. The resulting pseudorandom code word which is repeatedly generated is used by the decoding system to synchronize with the encoding system. A data decoder 131 in the decoding system is connected to the output of reference code generator 83 and determines whenever the k-bit data word appears which is used in the encoding system to generate the preamble pseudorandom binary code word. Upon detecting this signal decoder 131 supplies a pulse strobe signal, through OR gate 143 to the STROBE input of correlation detector 53 causing it to load the corresponding reference pseudorandom binary code word in the reference delay line cells of the correlation detector into the correlation detector multiplier circuit. This reference pseudorandom binary code word

is held in the multiplier circuit until a new reference pseudorandom binary code word can be loaded which occurs upon the occurrence of another strobe signal. The held reference pseudorandom code word is repeatedly compared in correlation detector **53** with the incoming preamble pseudorandom code and when a predetermined number of "matches" is found, the decoding system is considered synchronized with the encoding system.

To determine synchronization a counter **151** is connected to the output of correlation detector **53**. Counter **151** counts the "matches" found by the correlation detector and whenever a predetermined number of "matches" is found counter **151** sets flip-flop **145** which supplies a continuous strobe signal through OR gate **143** to the STROBE input of correlation detector **53**. This causes correlation detector **53** to continuously feed new reference code words as they appear from code generator **83** into the multiplier circuit for comparison with pseudorandom code words arriving from the encoding system. The strobe output of flip-flop **145** also enables a gate **141** which permits, when enabled, the output of correlation detector **53** (whether positive or negative) to be supplied to a transfer register **85**. The output of correlation detector **53** is always supplied to peak finder **63** to enable the translation error feedback loop, described in greater detail below, to operate during synchronization. After synchronization is achieved, transfer register **85** is operated by the positive output only of correlation detector **53** to output on n-bit data word corresponding to an arriving pseudorandom binary code word.

The synchronization detecting circuits including counter **151** and flip-flop **145** are reset upon the cessation of a transmission from the encoding system and this is recognized by a missing pulse detector **153** which supplies a signal which resets counter **151** and flip-flop **145** after the output of correlation detector **53** has disappeared for a predetermined length of time.

The predetermined number of preamble pseudorandom code words which are transmitted are sufficient in number to allow adequate time for the frequency translation error feedback loop, described below, to eliminate the effect of frequency translation errors at the input (and correspondingly the output) of correlation detector **53**).

If a data modifier **37** (FIG. **1**) was used in the encoding system, a similar data modifier **161** is required in the decoding system to detect the arriving pseudorandom binary code for the prohibited k-bit code word and to load transfer register **85** with the proper k-bit code word to which the arriving pseudorandom code word corresponds.

If data modifier **111** (FIG. **6**) is used in the encoding system to generate an inverted pseudorandom binary code word for a prohibited k-bit digital code word, the data demodifer **161** of FIG. **2** would be replaced by the circuit illustrated in FIG. **7**. In the FIG. **7** circuit, the correlation detector output (whether positive or negative) which appears at the output of gate **141** after synchronization is achieved (and the translation frequency error feedback loop is locked) is supplied to a negative pulse detector **137**. A characteristic of correlation detector **53** is that if an "inverted" arriving pseudorandom code word is compared with its "non-inverted" counterpart, a negative output signal occurs, the amplitude of which is determined by the degree of "non-match" between the compared code words. Thus, negative pulse detector **137** will determine when an "inverted" pseudorandom code word arrives from the encoding system. The output of negative pulse detector **137** is supplied to an input of AND gate **139** which receives at its other input the output of gate **141**. Gate **139** functions to inhibit the negative correlation detector output from gate **141** from being supplied to peak finder **63**. Thus the peak finder **63** is not affected by negative outputs of correlation detector **53** after the feedback loop described below is locked. The output of negative pulse detector is also supplied to a pulse generator **135** which generates a CLEAR signal which is supplied to transfer register **85**. This CLEAR signal causes the transfer register **85** to clear itself so its output lines assume an "all zero" state corresponding to the prohibited "all zero" k-bit digital code word which was modified in the encoding system. If a different prohibited k-bit digital code word is modified in the encoding system, the output of pulse generator **135** would be used to load transfer register **85** with the appropriate prohibited data word. Transfer register **85** is arranged so that only positive outputs of correlation detector will cause it to parallel load data from the reference code generator **83** so that whenever the "inverted" pseudorandom code word is detected transfer register **85** is not loaded with the output of reference code generator **83** but is merely cleared by the output of pulse generator **135** (or loaded with appropriate data by the output of pulse generator **135** if a prohibited k-bit data word is other than all zero sequence).

If correlation detector **53** were directly connected to the output of the high frequency receiver **43**, as would be the case in a normal correlation decoding system, the envelope of its output signal would be as shown in FIG. **4***a*, varying in amplitude and polarity in accordance with a sinusoidal signal component which is impressed upon the correlation signal output, having a frequency corresponding to that of the frequency translation error introduced during transmission and reception of the incoming digital code words. As shown in FIG. **4***a*, the nulls of the sinusoidal signal are such as to possibly result in a correlation output signal indicating a match being "missed" because the signal level is excessively low.

To eliminate this problem, the decoding system of the invention applies a frequency rotative component to the input of the correlation detector which, in effect, cancels the rotative component caused by the frequency translation error, thereby causing the correlation detector output phase to be stably maintained to produce an output signal of a relatively high level. This is accomplished by a feedback loop which includes peak finder **63**, low pass filter **65**, saw-tooth generator **87**, voltage control oscillator **73**, balance modulator **49**, and low pass filter **51**.

The feedback loop utilizes sawtooth generator **67** to provide a sawtooth waveform at the control input to voltage control oscillator **73** which varies the output frequency of oscillator **73** approximately symmetrically about the nominal chipping frequency f_c by an amount sufficient to encompass any anticipated translation error. For example, a 1 Hz sawtooth can be used which sweeps voltage control oscillator **73** over $f_c \pm 100$ Hz.

The effect of the feedback system is to find and maintain a first local carrier frequency (output of VCO **73**) whose frequency and phase maintain the output of correlation detector **53** at a level corresponding to the peak of the pseudorandom binary code word's correlation

function, thereby eliminating effects of the frequency translation of the input signal.

The peak filter **63** is a circuit which compares successive outputs from correlator detector **53** and generates an output which instructs the saw-tooth generator **67** to continue generating an increasing output waveform as long as the pulses from peak finder **63** are positive and the nth pulse is equal to or greater in amplitude than the n−1th pulse. This indicates that the output of the correlator **53** is at or is climbing towards a positive peak on the transfer frequency sinusoid (FIG. **4a**). When the nth pulse amplitude is less than the n−1th pulse, the saw-tooth generator is stopped and, if the decline continues, the output from the saw-tooth generator **67** will be reduced until a stable operation at or near the envelope peak illustrated in FIG. **4a** is achieved. The correlation detector **53** output, when the feedback loop is propertly locked is illustrated in FIG. **4b**.

Low pass filter **65**, provided between peak finder **63** and saw-tooth generator **67**, smooths the output from the peak finder **63** and makes the frequency generated by the voltage control oscillator **73** a function of the short term average of several pulses to prevent "hunting" and instability of the control loop.

An exemplary peak finding circuit **63** which may be used is illustrated in FIG. **5**. As shown therein, two sample and hold circuits **91** and **93** are provided for respectively receiving the nth and n−1th outputs from correlation detector **53**. The outputs of the two sample and hold circuits are then fed to a comparator **95** which provides a positive output whenever the nth sample is greater than the n−1th sample and a negative output whenever the reverse is true. No output is provided if the two samples are equal. The output from comparator **95** is fed to low pass filter **65**.

A mathematical analysis of the operation of the detranslation loop is as follows.

The incoming pseudorandom binary code words can be considered as an amplitude signal component, w_m (actually there are many components consisting of harmonics of the word repetition rate and the analysis applies to each component), and a w_t component which is the translation error component. Thus, the data exiting from high frequency receiver **43** can be expressed as:

$$A\cos(w_m+w_t)t \tag{1}$$

where w_t is a translation error component, w_m is a signal frequency component, and A is the amplitude of the signal component.

As result of modulating this signal on the output of voltage control oscillator **73**, the following signal is produced:

$$A\cos(w_m+w_t)t\times\cos(w_c+w_x) \tag{2}$$

where w_c represents the nominal center frequency of voltage control oscillator **73** and w_x is the deviation from w_c caused by the feedback loop.

Equation (2) can be rewritten as:

$$\tfrac{1}{2}A[\cos(w_c+w_m+w_x+w_t)t+\cos(w_c-w_m-w_t+w_x)t] \tag{3}$$

Low pass filter **51** removes the higher frequency component (the first half of equation 3) resulting in:

$$\tfrac{1}{2}A\cos(w_c-w_m-w_t+w_x)t \tag{4}$$

By varying the frequency component w_x with the detranslation loop so that it equals w_t equation 4 can be converted to $\frac{1}{2}A\cos(w_c-w_m)t$ so that w_t is eliminated. By using this signal to modulate a second carrier fixed in frequency at w_c, the following is obtained,

$$\tfrac{1}{2}A\cos(w_c-w_m)t\times\cos w_c=\tfrac{1}{4}A\cos[(2w_c-w_m)t+\cos w_mt] \tag{5}$$

After filtering to remove the term containing $2w_c$, the original $\cos w_mt$ term is obtained which will correlate with the locally generated reference pseudorandom code words without distortions due to translation error.

As a modification to the detranslation system illustrated in FIG. **2**, balanced modulator **52** and low pass filter **54** can be provided upstream of balanced modulator **49** and low pass filter **51**, as functionally achieved by connecting the output of oscillator **101** to the carrier frequency input of balanced modulator **52** and the output of VCO **73** to the carrier frequency input of balanced modulator **49**. Or, balanced modulator **32** and low pass filter **54** can be eliminated from the decoding system and instead provided in the encoding system just upstream of transmitter **41**, as illustrated in FIG. **3**.

As evident from the above, the described decoding system includes a detranslation loop which improves the quality of the correlation detector output by eliminating the effect of frequency translation errors thereat induced during the transmission and reception of a DC coded signal.

Although the decoding system illustrated in FIG. **2** may be used with the encoding system illustrated in FIG. **1**, the principles of operation of the decoding system allow its use with other types of code transmission systems which need not employ pseudorandom coding, so long as the leading k chips of a transmitted data code word used (or any other easily recognized set of k chips) are the same as the k bits of data used to select the transmitted code word. The encoding system illustrated in FIG. **1** does have advantages, however, in providing pseudorandom binary code words for transmission which have desirable correlation characteristics and in providing pseudorandom binary code words which have an equal number of ones and zeros to thereby maintain a DC balance for the transmitted signal which simplifies decoding circuitry.

Although representative embodiments of the invention have been illustrated, it should be clear that various modifications can be made to these embodiments without departing from the spirit and scope of the invention. Accordingly, the invention is not limited by the foregoing description, but is only limited by the claims which are appended hereto.

What is claimed is:

1. A digital communications system comprising:

means for generating a selected one of a plurality of n-bit binary code words from a received k-bit data word to provide a generated binary code word, where k and n are integers;

means for transmitting said generated binary code word;

means coupled to said transmitting means for receiving said generated binary code word;

first modulation means for modulating the output of a variable frequency local oscillator having a predetermined center frequency with said generated binary code word;

second modulation means for modulating the output of a fixed frequency local oscillator with the output of said first modulation means;

a reference code generator for generating a plurality of digital reference code words;

correlation means coupled to the output of said second modulation means and said reference code generator for comparing each of said digital reference code words with said generated binary code word and for providing a correlation output signal representing the correlation of one of said plurality of digital reference code words with said generated binary code word;

means responsive to a changing characteristic of said correlation output signal for determining a frequency translation error which occurred during transmission and reception of said generated binary code word; and,

means responsive to said determining means for adjusting the frequency of the output of said variable frequency oscillator in a direction to minimize the effect of said frequency translation error at the output of said correlation means.

2. A digital communications system comprising:

means for generating a selected one of a plurality of n-bit binary code words from a received k-bit data word to provide a generated binary code word, where k and n are integers;

means for transmitting said generated binary code word;

means coupled to said transmitting means for receiving said generated code word;

first modulating means for modulating the output of a fixed frequency local oscillator with said generated binary code word;

second modulating means for modulating the output of a variable frequency local oscillator with the output of said first modulation means;

a reference code generator for generating a plurality of digital reference code words;

correlation means coupled to the output of said second modulation means and said reference code generator for comparing each of said reference digital code words with said generated binary code word and for providing a correlation output signal representing the correlation of one of said plurality of digital reference code words with said generated binary code word;

means responsive to a changing characteristic of said correlation output signal for determining a frequency translation error which occurred during transmission and reception of said generated binary code word; and,

means responsive to said determining means for adjusting the frequency of the output of said variable frequency oscillator in a direction to minimize the effect of said frequency translation error at the output of said correlation means.

3. A data communications system as in claims **1** or **2** wherein $n=2^k$.

4. A data communications system as in claims **1** or **2** wherein $n=2^k-1$.

5. A data communications system as in claim **2** wherein said first modulating means coupled to the output of said receiving means.

6. A data communications system as in claim **2** wherein said first modulating means is coupled to the output of said generating means.

7. A data communications system as in claims **1** or **2** wherein each of said plurality of binary code words represents a particular start-stop phase of a repeating n-bit binary code pattern.

8. A data communications system as in claim **1** or **2** wherein said generating means generates an inverted one of said plurality of n-bit binary code words for at least one predetermined received k-bit data word.

9. A data communications system as in claims **1** or **2** wherein said adjusting means comprises a sawtooth wave generator, the output of which adjusts the output frequency of said voltage controlled oscillator, said sawtooth wave generator having its output voltage fixed at a point in a sawtooth waveform cycle which exists when said determining means determines that a peak value has occurred in the envelope of the output of said correlation means.

10. A data communiations system as in claim **9** wherein said determining means is a signal peak detecting means which determines the peak level of the envelope of said correlation means output signal.

11. A data communications system as in claim **10**, further comprising a low pass filter connected between said signal peak detecting means and said sawtooth wave generator, said low pass filter smoothing the output of said signal peak detecting means.

12. A data communications system as in claims **1** or **2** wherein each of said first and second modulation means comprises a balanced modulator and a low pass filter connected to the output of said balanced modulator.

13. A data communications system as in claims **1** or **2** wherein said plurality of binary code words and said plurality of digital reference code words are pseudorandom binary code words.

14. A data communications system as in claim **3** wherein said plurality of binary code words each contain an equal number of ones and zeros.

15. An encoding system for transmitting digital code data comprising:

means for receiving k-bit data words;

means for generating from a received k-bit data word, a selected one of a plurality of n-bit pseudorandom code sequences which is assigned to said received k-bit data word and for adding to said selected pseudorandom code sequence at least one additional binary bit to produce a pseudorandom code word which contains an even number of data bits, half of which are of ones and half of which are zeros; and

means for tansmitting said pseudorandom code word at a predetermined chipping frequency to a receiver.

16. An encoding system as in claim **15** wherein said means for generating said pseudoramdom word code comprises: a pseudorandom code generator which receives said k-bit data word and generates, at an output thereof, said selected pseudorandom code sequence and, means for temporarily halting operation of said pseudorandom code generator and inserting at least one additional binary bit at the output of said pseudorandom code generator in response to the detection of a predetermined state of said pseudorandom code generator.

17. An encoding system as in claim **16** wherein said at least one additional binary bit is generated by halting operation of said pseudorandom code generator for a predetermined number of its operating clock cycles such that said at least one additional binary bit is generated at the time of said halting by the immediately pre-

ceeding output state of said pseudorandom code generator.

18. An encoding system as in claim 16 further comprising means for modifying a received k-bit data word when it represents a predetermined digital value and supplying said modified k-bit data word to said pseudorandom code generator.

19. An encoding system for transmitting digital code data comprising:

means for receiving k-bit data words;

means for generating from a received k-bit data word a selected one of a plurality of n-bit pseudorandom code words which is assigned to said received k-bit data word, said means for generating being responsive to at least one predetermined k-bit data word to generate one of said plurality of pseudorandom code words with an inverted polarity; and,

means for transmitting the pseudorandom code words produced by said generating means.

20. A data decoding system comprising:

means for receiving a plurality of n-bit binary code words respectively generated from k-bit data words, where k and n are integers;

first modulating means for modulating the output of a variable frequency oscillator having a predetermined center frequency with said received n-bit binary code words;

second modulation means for modulating the output of a fixed frequency local oscillator with the output of said receiving means;

a reference code generator for generating a plurality of digital reference code words;

correlation means coupled to the output of said second modulation means and said reference code generator for comparing each of said digital reference code words with said generated binary code word and for providing a correlation output signal representing the correlation of one of said plurality of digital reference code words with said generated binary code word;

means responsive to a changing characteristic of said correlation output signal for determining a frequency translation error which occurred during transmission and reception of said generated binary code word; and,

means responsive to said determining means for adjusting the frequency of the output of said voltage controlled oscillator in a direction to minimize the effect of said frequency translation error at the output of said correlation means.

21. A data decoding system comprising:

means for receiving a plurality of n-bit binary code words respectively generated from k-bit data words, where k and n are integers, said n-bit binary code words being modulated by first modulation means on the output of a fixed frequency oscillator;

second modulation means for modulating the output of a variable frequency local oscillator with the output of said first modulation means;

a reference code generator for generating a plurality of digital reference code words;

correlation means coupled to the output of said second modulation means and said reference code generator for comparing each of said digital reference code words with said generated binary code word and for providing a correlation output signal representing the correlation of one of said plurality of digital reference code words with said generated binary code word;

means responsive to a changing characteristic of said correlation output signal for determining a frequency translation error which occurred during transmission and reception of said generated binary code word; and,

means responsive to said determining means for adjusting the frequency of the output of said voltage controlled oscillator in a direction to minimize the effect of said frequency translation error at the output of said correlation means.

22. A data decoding system as in claims 20 or 21 wherein $n=2^k$.

23. A data decoding system as in claims 20 or 21 wherein $n=2^k-1$.

24. A data decoding system as in claims 20 or 21 wherein each of said plurality of binary code words represents a particular start-stop phase of a repeating n-bit binary code pattern.

25. A data decoding system as in claim 22 wherein said plurality of binary code words each contain an equal number of ones and zeros.

26. A data decoding system as in claims 20 or 21 wherein said adjusting means comprises a sawtooth wave generator, the output of which adjusts the output frequency of said voltage controller oscillator, said sawtooth wave generator having its output voltage fixed at a point in a sawtooth waveform cycle which exists when said determining means determines that a peak value has occurred in the envelope of the output of said correlation means.

27. A data decoding system as in claim 26 wherein said determining means is a signal peak detecting means which determines the peak level of the envelope of said correlation means output signal.

28. A data decoding system as in claim 27 further comprising a low pass filter connected between said signal peak detecting means and said sawtooth wave generator, said low pass filter smoothing output of said signal peak detecting means.

29. A data decoding system as in claim 20 wherein each of said first and second modulation means comprises a balanced modulator and a low pass filter connected to the output of said balanced modulator.

30. A decoding system as in claim 21 wherein said second modulation means comprises a balanced modulator and a low pass filter connected to the output of said balanced modulator.

31. A data decoding system as in claims 20 or 21 wherein said plurality of binary code words and said plurality of digital reference code words are pseudorandom binary code words.

* * * * *

more particularly from the comparator in the ACSU **234**. The SMU **206** processes the signal received from the ACSU **204**, and generates a digital binary data output signal in response which is received by the parity decoder **140**, as illustrated in FIG. 1B. For more detail, refer to U.S. patent application Ser. No. 09/896,134, entitled "METHOD AND APPARATUS FOR VITERBI DETECTOR STATE METRIC RE-NORMALIZATION", filed Jun. 29, 2001, and incorporated by reference herein.

Disclosed herein is a method of calibrating the parameters of a Viterbi detector **138** in which each branch metric is calculated based on noise statistics that depend on the signal hypothesis corresponding to the branch. For more detail, refer to the above captioned patent application entitled "METHOD AND APPARATUS FOR A DATA-DEPENDENT NOISE PREDICTIVE VITERBI", herein incorporated by reference. While the disclosed embodiments are discussed in relation to Viterbi detectors used in hard disk read channels, it will be appreciated that the disclosed embodiments may also be used with Viterbi detectors utilized for other purposes such as other recording or communications technologies.

The Viterbi detection algorithm for estimating the transmitted signal in noisy received data is well known. The algorithm uses dynamic programming to compute the maximum likelihood estimate of the transmitted signal from the received data, where the likelihood is computed assuming a particular model of the noise statistics in the received data.

In prior Viterbi detectors, the maximum likelihood estimate of transmitted data is computed assuming that the noise is stationary. In particular, it is assumed that the noise is independent of the transmitted signal. This assumption allows a simplified detector, but with stronger correlations between noise and the transmitted signal, the simplified detector's performance increasingly falls below true maximum likelihood performance.

In recording technologies as practiced today, physical imperfections in the representation of recorded user data in the recording medium itself are becoming the dominate source of noise in the read back data. This noise is highly dependent on what was (intended to be) written in the medium. Prior Viterbi detectors, that assume a stationary noise model, cannot exploit this statistical dependence of the noise on the signal.

An exemplary architecture **300** for a branch metric unit **202** for use with a noise predictive Viterbi detector is shown in FIG. **3**A. A feature of this architecture **300** is that the branch metrics **306** (and their corresponding square difference operators) are clustered into multiple groups **306**A–D, where all the members of each group draw input from a single, shared noise predictive filter **304**A–D corresponding to the group. In the case illustrated, the 32 branch metrics **306** are divided into eight groups, four of which **306**A–D are shown, each group having four members. For more detail, refer to the above captioned patent application "METHOD AND APPARATUS FOR A DATA-DEPENDENT NOISE PREDICTIVE VITERBI".

An exemplary three tap **310**A–C FIR filter **304**A–D for use with the branch metric unit **202** of FIG. **3**A is shown in FIG. **3**B. The FIR filter **304**A–D is designed to filter out as much noise from the signal as possible prior to Viterbi processing where the detector tries to figure out what the signal is. The problem is that noise is generally unpredictable as it comes from many different factors. The unpredictable nature of noise makes it difficult to separate the noise from the signal. Typical FIR filters strike a balance between filtering as much noise as possible and ensuring that only a minimal amount of the signal is lost in the process. If the noise being looked for can be predicted, it becomes easier to more accurately separate and remove that noise from the signal without compromising the signal.

1 Overview

An algorithm for calculating the parameters, such as optimized filter coefficients, of data-dependent noise predictive filters **304**A–D is presented. The algorithm has two phases: a noise statistics estimation or training phase and a filter calculation phase. The training phase is typically performed using hardware built into the read channel device **108**, as will be described below. Alternatively, training may be performed using off-chip hardware and/or software or a combination of off-chip and on-chip hardware and/or software. During the training phase, products of pairs of noise samples are accumulated in order to estimate the noise correlations. During this phase, the read channel device **108** acts as a noise statistic measurement tool which acquires noise statistics while reading back "known" data from the disk drive **100** as would be done during normal operation. These noise statistic measurements are then provided to external hardware and/or software to perform the calculation phase of the disclosed calibration method, as described below. Typically, the read channel device **108** is instructed by an external device to perform such measurements. In one embodiment, the hard disk drive **100** including the read channel device **108** further includes a micro-controller **110** which, in addition to the hardware and/or software/firmware to operate the drive **100**, includes hardware and/or software/firmware to calibrate the read channel device **108** as described. The micro-controller **10** controls the read channel device **108** to acquire the necessary statistic samples and perform the calculations as described below. In an alternate embodiment, the read channel device **108** itself contains the hardware and/or software necessary to perform self-calibration.

The calculation phase is typically performed off-chip, i.e. not on the read channel device **108**, and is described in below. The calculation phase may be performed by any device capable of performing the requisite computations and capable of interfacing with the read channel device **108** to receive the measured noise statistics and provide the computed Viterbi parameters. In one embodiment, as described above, the calculation phase is performed by the micro-controller **10** of the hard disk drive **100** which includes the read channel device **108**.

Further, calibration, including both the training and calculation phases, is typically performed during manufacturing of the device, such as a hard disk drive **100**, which will include the read channel device **108**. During manufacture of a particular hard disk drive **100**, the optimal parameters for the noise predictive Viterbi detector of that drive are determined, as disclosed. Once these parameters are determined, they are stored in the drive **100** in some form of non-volatile storage which permits the parameters to be downloaded into the read channel device **108** during operation. In one alternative device, the read channel device **108** itself provides non-volatile storage to store these parameters. In yet another alternative device, hardware to support both the training and calculation phases for calibration is provided to permit calibration in the field, periodic re-calibration of an installed device and/or real time adaptive calibration.

The question of how much training is enough is also considered below. Further, the results of the training phase are used to estimate how wide (in bits) the noise correlation

RAKE COMBINING METHODS AND APPARATUS USING WEIGHTING FACTORS DERIVED FROM KNOWLEDGE OF SPREADING SPECTRUM SIGNAL CHARACTERISTICS

CROSS-REFERENCE TO RELATED APPLICATION

This application is related to application Ser. No. 09/344,898, filed concurrently herewith, entitled Multi-Stage Rake Combining Methods and Apparatus, to Bottomley et al., assigned to the assignee of the present application. The disclosure of this application is hereby incorporated herein by reference.

FIELD OF THE INVENTION

The present invention relates to communications methods and apparatus, and more particularly, to spread spectrum communications methods and apparatus.

BACKGROUND OF THE INVENTION

Wireless communications systems are commonly employed to provide voice and data communications to subscribers. For example, analog cellular radiotelephone systems, such as those designated AMPS, ETACS, NMT-450, and NMT-900, have long been deployed successfully throughout the world. Digital cellular radiotelephone systems such as those conforming to the North American standard IS-54 and the European standard GSM have been in service since the early 1990's. More recently, a wide variety of wireless digital services broadly labeled as PCS (Personal Communications Services) have been introduced, including advanced digital cellular systems conforming to standards such as IS-136 and IS-95, lower-power systems such as DECT (Digital Enhanced Cordless Telephone) and data communications services such as CDPD (Cellular Digital Packet Data). These and other systems are described in *The Mobile Communications Handbook*, edited by Gibson and published by CRC Press (1996).

FIG. **1** illustrates a typical terrestrial cellular radiotelephone communication system **20**. The cellular radiotelephone system **20** may include one or more radiotelephones (terminals) **22**, communicating with a plurality of cells **24** served by base stations **26** and a mobile telephone switching office (MTSO) **28**. Although only three cells **24** are shown in FIG. **1**, a typical cellular network may include hundreds of cells, may include more than one MTSO, and may serve thousands of radiotelephones.

The cells **24** generally serve as nodes in the communication system **20**, from which links are established between radiotelephones **22** and the MTSO **28**, by way of the base stations **26** serving the cells **24**. Each cell **24** will have allocated to it one or more dedicated control channels and one or more traffic channels. A control channel is a dedicated channel used for transmitting cell identification and paging information. The traffic channels carry the voice and data information. Through the cellular network **20**, a duplex radio communication link may be effected between two mobile terminals **22** or between a mobile terminal **22** and a landline telephone user **32** through a public switched telephone network (PSTN) **34**. The function of a base station **26** is to handle radio communication between a cell **24** and mobile terminals **22**. In this capacity, a base station **26** functions as a relay station for data and voice signals.

As illustrated in FIG. **2**, a satellite **42** may be employed to perform similar functions to those performed by a conventional terrestrial base station, for example, to serve areas in which population is sparsely distributed or which have rugged topography that tends to make conventional landline telephone or terrestrial cellular telephone infrastructure technically or economically impractical. A satellite radiotelephone system **40** typically includes one or more satellites **42** that serve as relays or transponders between one or more earth stations **44** and terminals **23**. The satellite conveys radiotelephone communications over duplex links **46** to terminals **23** and an earth station **44**. The earth station **44** may in turn be connected to a public switched telephone network **34**, allowing communications between satellite radiotelephones, and communications between satellite radio telephones and conventional terrestrial cellular radiotelephones or landline telephones. The satellite radiotelephone system **40** may utilize a single antenna beam covering the entire area served by the system, or, as shown, the satellite may be designed such that it produces multiple minimally-overlapping beams **48**, each serving distinct geographical coverage areas **50** in the system's service region. The coverage areas **50** serve a similar function to the cells **24** of the terrestrial cellular system **20** of FIG. **1**.

Several types of access techniques are conventionally used to provide wireless services to users of wireless systems such as those illustrated in FIGS. **1** and **2**. Traditional analog cellular systems generally employ a system referred to as frequency division multiple access (FDMA) to create communications channels, wherein discrete frequency bands serve as channels over which cellular terminals communicate with cellular base stations. Typically, these bands are reused in geographically separated cells in order to increase system capacity.

Modern digital wireless systems typically utilize different multiple access techniques such as time division multiple access (TDMA) and/or code division multiple access (CDMA) to provide increased spectral efficiency. In TDMA systems, such as those conforming to the GSM or IS-136 standards, carriers are divided into sequential time slots that are assigned to multiple channels such that a plurality of channels may be multiplexed on a single carrier. CDMA systems, such as those conforming to the IS-95 standard, achieve increased channel capacity by using "spread spectrum" techniques wherein a channel is defined by modulating a data-modulated carrier signal by a unique spreading code, i.e., a code that spreads an original data-modulated carrier over a wide portion of the frequency spectrum in which the communications system operates.

Conventional spread-spectrum CDMA communications systems commonly use so-called "direct sequence" spread spectrum modulation. In direct sequence modulation, a data-modulated carrier is directly modulated by a spreading code or sequence before being amplified by a power amplifier and transmitted over a communications medium, e.g., an air interface. The spreading code typically includes a sequence of "chips" occurring at a chip rate that typically is much higher than the bit rate of the data being transmitted.

Typical transmit operations of such a system are illustrated in FIG. **3**. Data streams from different users are subjected to various signal processing steps, such as error correction coding or interleaving, and spread using a combination of a user specific spreading code and a group-specific scrambling code. The coded data streams from the users are then combined, subjected to carrier modulation and transmitted as a composite signal in a communications medium.

A so-called Rake receiver structure is commonly used to recover information corresponding to one of the user data

streams. In a typical Rake receiver, a received composite signal is typically correlated with a particular spreading sequence assigned to the receiver to produce a plurality of time-offset correlations, a respective one of which corresponds to an echo of a transmitted spread spectrum signal. The correlations are then combined in a weighted fashion, i.e., respective correlations are multiplied by respective weighting factors and then summed to produce a decision statistic.

Several approaches to determining appropriate weighting factors have been proposed. Classical optimal Rake receivers typically are designed with an underlying assumption of uncorrelated noise at the receiver, and thus typically use the complex conjugates of channel coefficients estimated by a channel estimator as weighting factors. Such an approach may yield less than desirable results in CDMA systems, because the passing of interfering signals through the dispersive medium generally introduces correlation into the noise at the receiver. Accordingly, receiver approaches have been proposed based on a model of "colored" noise, as described, for example, in "A Noise Whitening Approach to Multiple Access Noise Rejection-Part I: Theory and Background," by Monk et al., *IEEE Journal on Selected Areas in Communications*, vol. 12, pp., 817–827(June 1994); "A Noise Whitening Approach to Multiple Access Noise Rejection-Part II: Implementation Issues," by Monk et al., *IEEE Journal on Selected Areas in Communications*, vol. 14, pp. 1488–1499 (October 1996); "Data Detection Algorithms Specifically Designed for the Downlink of CDMA Mobile Radio Systems," by Klein, 1997 IEEE Vehicular Technology Conference, Phoenix Ariz. (May 4–7, 1997); U.S. Pat. No. 5,572,552 to Dent et al. (issued Nov. 5, 1996); and "Optimizing the Rake Receiver for Demodulation of Downlink CDMA Signals," by Bottomley, *Proceedings of the 43rd IEEE Vehicular Technology Conference*, Secaucus N.J. (May 18–20, 1993).

Although such approaches can be effective in improving reception of spread-spectrum signals, there is an ongoing need for improved techniques for processing received spread spectrum signals that account for interference from other spread spectrum signals.

SUMMARY OF THE INVENTION

In light of the foregoing, it is an object of the present invention to provide improved methods and apparatus for recovering information represented by a spread spectrum signal transmitted in a communications medium.

It is another object of the present invention to provide improved methods and apparatus for recovering information represented by a spread spectrum signal that can compensate for interference from other spread spectrum signals transmitted in the communications medium.

These and other objects, features and advantages can be provided, according to the present invention, by methods and apparatus in which correlations of a received composite signal with a desired spreading sequence are weightedly combined using weighting factors that are generated based on knowledge of the spread spectrum signals present in the composite signal, including pulse shape information, e.g., based on the statistical properties of the desired sequence and power of the interfering spread spectrum signals using other sequences. More particularly, the weighting factors may be generated from a composite channel response estimated using the statistical properties of the desired sequence and an impairment correlation determined from a power estimate of at least one other spread spectrum signal and noise present in the composite signal. According to an aspect of the present invention, updated weighting factors are iteratively estimated from previously computed weighting factors, obviating the need to perform inversion of an impairment correlation matrix.

In particular, according to the present invention, information encoded in a first spread spectrum signal transmitted according to a first spreading sequence in a communications medium is recovered. A composite signal including the first spread spectrum signal is received from the communications medium. The composite signal is correlated with the first spreading sequence to produce a plurality of time-offset correlations of the composite signal with the first spreading sequence. Weighting factors are generated based on knowledge of spread spectrum signals present in the composite signal, including pulse shaping information. The correlations are combined according to the weighting factors to estimate information encoded in the transmitted first spread spectrum signal.

According to one embodiment of the present invention, a composite channel response is estimated from knowledge of the first spreading sequence. An impairment correlation is estimated from knowledge of the first spreading sequence, an estimate of power of a second spread spectrum signal in the composite signal, and an estimate of power of noise in the composite signal. Weighting factors are then generated from the estimated composite channel response and the estimated impairment correlation.

According to another embodiment of the present invention, a multiuser interference correlation and a noise correlation are estimated. The estimated multiuser interference correlation and the estimated noise correlation are then summed to estimate the impairment correlation. An intersymbol interference correlation may also be estimated, and added to the estimated multiuser interference correlation and the estimated noise correlation to estimate the impairment correlation.

According to another aspect of the present invention, weighting factors are iteratively generated from an estimated channel response, an estimated impairment correlation, and previously determined weighting factors. A composite signal including a first spread spectrum signal is received from the communications medium. The composite signal is correlated with the first spreading sequence to produce a plurality of time-offset correlations of the composite signal with the first spreading sequence. The correlations are combined according to the iteratively generated weighting factors to estimate information encoded in the transmitted first spread spectrum signal. The channel response may be a composite channel response estimated from knowledge of the first spreading sequence, and the impairment correlation may be estimated from knowledge of the first spreading sequence, an estimate of power of a second spread spectrum signal in the composite signal, and an estimate of power of noise in the composite signal.

According to another aspect of the present invention, an apparatus for recovering information encoded in a first spread spectrum signal transmitted in a communications medium includes means for receiving a composite signal including the first spread spectrum signal from the communications medium. Means are provided, responsive to the means for receiving, for correlating the composite signal with the first spreading sequence to produce a plurality of time-offset correlations of the composite signal with the first spreading sequence. Means are provided for generating weighting factors based on knowledge of spread spectrum

recovers information represented by a spread spectrum signal transmitted according to a desired spreading sequence s_d from a composite signal r(t) received from a communications medium. The receiver **400** includes means for receiving the composite signal r(t), e.g., a radio processor **405** that performs such operations as amplifying the signal r(t), mixing, filtering and producing baseband samples r(k) of the received signal r(t). A correlation unit **410**, here shown as a bank of delays **412***a*–**412**L linked to a bank of correlators **414***a*–**414**L, correlates delayed versions of the baseband signal r(k) to the desired spreading sequence s_d. It will be appreciated that the radio processor **405** may perform a variety of other functions, and that the correlation unit **410** may be implemented in other forms, such as by using a sliding correlator.

The correlations $x_1, x_2, \ldots, x_j$ produced by the correlation unit **410** are combined in a weighted combiner **420** that uses weighting factors w generated by a weighting factor generator **430** based on knowledge of spread spectrum signals transmitted in the communications medium from which the composite signal r(t) is received. As will be shown in detail below, this may include information on the statistical properties of the desired spreading sequence s_d, as well as information about power of other spread spectrum signals included in the composite signal r(t). The weighted combiner **420** produces a decision statistic z that may then be used by a detector **440** to estimate information represented by the originally transmitted spread spectrum signal corresponding to the desired spreading sequence s_d The detector **440** may, for example, employ soft decision decoding, such as convolutional or turbo decoding.

It will be appreciated that the receiver **400** of FIG. **4** may be implemented in a number of different ways. Although the description herein refers to employment of the receiver **400** in a mobile or other terminal that is operative to communicate with a base station of a wireless communications system, the receiver **400** can be implemented in a number of other forms including, but not limited to, receivers used in cellular base station transceivers, satellite transceivers, wireline transceivers, and other communications devices. The correlation unit **410**, weighted combiner **420**, weighting factor generator **430** and detector **440** may be implemented using, for example, an application-specific integrated circuit (ASIC), digital signal processor (DSP) chip or other processing device configured to perform the described processing functions. It will also be understood that, in general, these and other components of the receiver **400** may be implemented using special-purpose circuitry, software or firmware executing on special or general-purpose data processing devices, or combinations thereof.

The combining operations performed by the weighted combiner **420** may be expressed as:

$$z = w^H x, \text{ or} \tag{1}$$

$$z = Re\{w^H x\},$$

where z is the decision statistic produced by the combiner **420**, w and x are vectors representing the weighting factors and the correlation outputs, respectively, and Re {} denotes the real part of the argument. The decision statistic can be used, for example, to determine a bit value (e.g., by using the sign of the decision statistic), or to provide soft values for subsequent decoding.

According to a preferred embodiment of the present invention, the weighting factors w generated by the weighting factor generator **430** are determined by first estimating a channel response and power of "own-cell" interfering spread spectrum signals (e.g., signals from the same base station) and noise. The channel response estimate and statistical properties of the desired spreading sequence s_d are then used to determine a "composite" channel (impulse) response h, which reflects effects of the transmit pulse shape filter and/or other elements on the transmitting end, as well as the effects of the communications medium and the response of the receive filter. The channel estimate and the power estimates are used to determine an overall impairment correlation R that includes respective components attributable to own-cell interference, other-cell interference and thermal noise, to obtain an overall impairment correlation matrix R. The composite channel response h and the overall impairment correlation R are then used to compute the weighting factors w.

The weighting factors w are derived taking into account the statistical properties of the spreading sequences, and more particularly, may be explicitly calculated using information related to the spreading sequences and the transmitted spread spectrum signals with which they are associated. Weighting factors w can be intermittently calculated, for example, upon substantial changes in the delays **412***a*–**412**L and the channel estimates.

It can be shown that given a set of correlator delays $(d_1, d_2, \ldots, d_j)$, where J is the number of correlators, the optimal combining weights to be used in the weighted combiner **420** may be expressed as:

$$w \triangleq (w_1, w_2 \ldots, w_j)^T = R^{-1} h, \tag{2}$$

where h is the composite channel response, including the transmit filter, medium, and receive filter responses, and R is the impairment correlation matrix.

It can be further shown that the composite channel response h is given by:

$$h_j = \frac{1}{N} \sum_{l=0}^{L-1} c_l \sum_{m=1-N}^{N-1} C(m) R_p(d_j + mT_c - \tau_l), \tag{3}$$

where c_l and τ_l are related to the medium response

$$c(t) = \sum_{l=0}^{L-1} c_l \delta(t - \tau_l),$$

L is the number of multipaths, N is the spreading factor, T_c is the chip duration, $R_p(t)$ is the autocorrelation function of the chip waveform, and C(m) is the aperiodic autocorrelation function of the spreading sequence defined as:

$$C(m) = \begin{cases} \sum_{n=0}^{N-1-m} s(n) s*(n+m), & 0 \le m \le N-1 \\ \sum_{n=0}^{N-1+m} s(n-m) s*(n), & 1-N \le m < 0 \end{cases} \tag{4}$$

where s(n) is the nth chip of the spreading sequence.

As a potentially simpler alternative, h_j may be estimated directly using a pilot channel, a pilot symbol, or decoded symbols.

The impairment correlation matrix R can be decomposed into three terms.:

$$R = R_{ISI} + R_{MUI} + R_n, \tag{5}$$

where R_{ISI}, R_{MUI}, and R_n, are the correlation of the intersymbol interference, the correlation of multiuser (e.g., intracell) interference, and correlation of additive white noise, respectively.

These components of R can be computed by the following expressions:

$$R_{ISI}(d_1, d_2) = \frac{1}{N^2}\sum_{l=0}^{L-1}\sum_{q=0}^{L-1}\sum_{i=-\infty, i\neq 0}^{\infty} c_l c_q^* \sum_{m=1-N}^{N-1}(N-|m|)\times R_p(d_1 + mT_c - iT - \tau_l)R_p^*(d_2 + mT_c - iT - \tau_q) \tag{6}$$

$$R_{MUI}(d_1, d_2) = \frac{\gamma_I}{N^2}\sum_{l=0}^{L-1}\sum_{q=0}^{L-1}\sum_{i=-\infty}^{\infty} c_l c_q^* \sum_{m=1-N}^{N-1}(N-|m|)\times R_p(d_1 + mT_c - iT - \tau_l)R_p^*(d_2 + mT_c - iT - \tau_q)(1-\alpha\delta(m)\delta(i)) \tag{7}$$

and

$$R_n(d_1, d_2) = \frac{\gamma_N}{N}\sum_{m=1-N}^{N-1} C(m)R_p(d_1 - d_2 + mT_c) \tag{8}$$

where γ_1 is the multiuser interference to signal power ratio, and γ_n is the noise to signal power ratio. The variable αin (12) takes values on $\{1, 0\}$; if orthogonal spreading is used, α=1, whereas if pseudo random spreading is used, α=0. By considering various combinations (including combinations other than d_1, d_2), all elements of the impairment correlation matrix R can be obtained (the infinite summation in i can be truncated to include only significant terms, e.g., i=−1, 1). From the above equations, if the receiver has the knowledge of (1) the channel impulse response c(t), (2) the autocorrelation function of the chip waveform $R_p(t)$, (3) the interference to signal ratio (y_1), (4) the noise to signal ratio y_n, and (5) the aperiodic auto-correlation function of the spreading sequence C(m), the weighting factors w can be computed explicitly.

In many applications, multiuser interference is much stronger than inter-symbol interference. Accordingly, the impairment correlation R matrix can be approximated by:

$$R \approx R_{MUI} + R_n \tag{9}$$

In this case, these terms include a common scaling factor, a signal power S in the ratios y_1, Y_N. This term can be omitted, so that only the interference power I and noise power need be estimated. Alternatively, signal power can be estimated and used to estimate the ratios y_1, y_N.

Furthermore, in practice it may be cumbersome to calculate the aperiodic autocorrelation function C(m), as such a function typically varies from symbol to symbol. To reduce the complexity of weight calculation, an average aperiodic autocorrelation function $\overline{C}(m)$ can be used instead, as given by:

$$\overline{C}(m) = N\delta(m) \tag{10}$$

Using equations (9) and (10), equations (7) and (8) can be greatly simplified.

In handoff or transmit diversity scenarios, the interference as a result of multiuser signals from multiple base stations typically is colored in its own way by the channel response, and the multiuser interference component R_{MUI} can be calculated by:

$$R_{MUI}(d_1, d_2) = \sum_{k=1}^{K}\left\{\begin{array}{c}\frac{\gamma_I^{(k)}}{N^2}\sum_{i=-\infty}^{\infty}\sum_{l=0}^{L-1}\sum_{q=0}^{L-1} c_l^{(k)}(c_q^{(k)})^* \sum_{m=1-N}^{N-1}(N-|m|)\times \\ R_p\left(d_1 + mT_c - iT - \tau_l^{(k)}\right) \\ R_p^*(d_2 + mT_c - iT - \tau_q^{(k)})(1-\alpha_k\delta(m)\delta(i))\end{array}\right\} \tag{11}$$

where superscript k is used for indexing base stations, and k=1 corresponds to the base station transmitting the desired spread spectrum signal. Typically, when orthogonal spreading is used, α_1=1 while α_k=0, for k≠1.

FIG. **5** illustrates an exemplary weighting factor generator **430** according to an embodiment of the present invention. The weighting factor generator **430** includes a channel estimator **510** that estimates channel tap coefficients c_l, and an aperiodic autocorrelation calculator **520** that determines a value of the aperiodic autocorrelation function C(m). The channel tap coefficients c, and the value of the periodic autocorrelation function C(m) are supplied to a composite channel response calculator **530** that calculates the composite channel response h based on the statistical properties of the desired spreading sequence, i.e., the autocorrelation $R_p(t)$ of the chip pulse shape (waveform), using equation (3). As noted above, a composite channel response may be calculated directly from correlations corresponding to a pilot channel, a pilot symbol, or a decoded symbol.

The weighting factor determiner **430** also includes an impairment correlation calculator **540** that computes an impairment correlation R according to equation (5). The impairment correlation calculator **540** includes a power estimator **542** that supplies signal power ratios γ_i,γ_N that are supplied to respective multiuser interference correlation and noise correlation calculators **546**, **548** that compute multiuser interference correlation and noise correlation components R_{MUI}, R_N, respectively, according to equations (7) and (8). An intersymbol interference correlation calculator **544** calculates an intersymbol interference correlation component R_{ISI}. The intersymbol interference impairment correlation, multiuser interference correlation and noise correlation components R_{MUI}, R_N, R_{ISI}, are summed by a summer **549** to produce the impairment correlation R, which is used, along with the composite channel response h, to generate weighting factors w in a weighting factor calculator **550**.

It will be understood that the apparatus illustrated in FIG. **5** may be modified along the lines suggested above. For example, the aperiodic autocorrelation calculator **520** may be eliminated, with the average aperiodic autocorrelation $\overline{C}(m)$ being substituted for the calculated aperiodic autocorrelation C(m), as described above in reference to equations (10), (8) and (3). The intersymbol interference impairment correlation calculator **544** may also be eliminated, along the lines described in reference to equation (9).

Further s implification in determining weighting factors w can be achieved by using an iterative approach that obviates the need to compute the inverse R^{-1} of the impairment correlation R to determine the weighting factors w. As illustrate in FIG. **6**, the weighting fact or generator **430** may include an iterative weighting factor calculator **550'** that iteratively calculates weighting factors w from previously computed or otherwise provided weighting factors, using the composite channel response h and impairment correlation R provided by the composite channel response calculator **530** and the impairment correlation calculator **540**, respectively.

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(54) **METHOD AND APPARATUS FOR COMBINING WEIGHT COMPUTATION IN A DS-CDMA RAKE RECEIVER**

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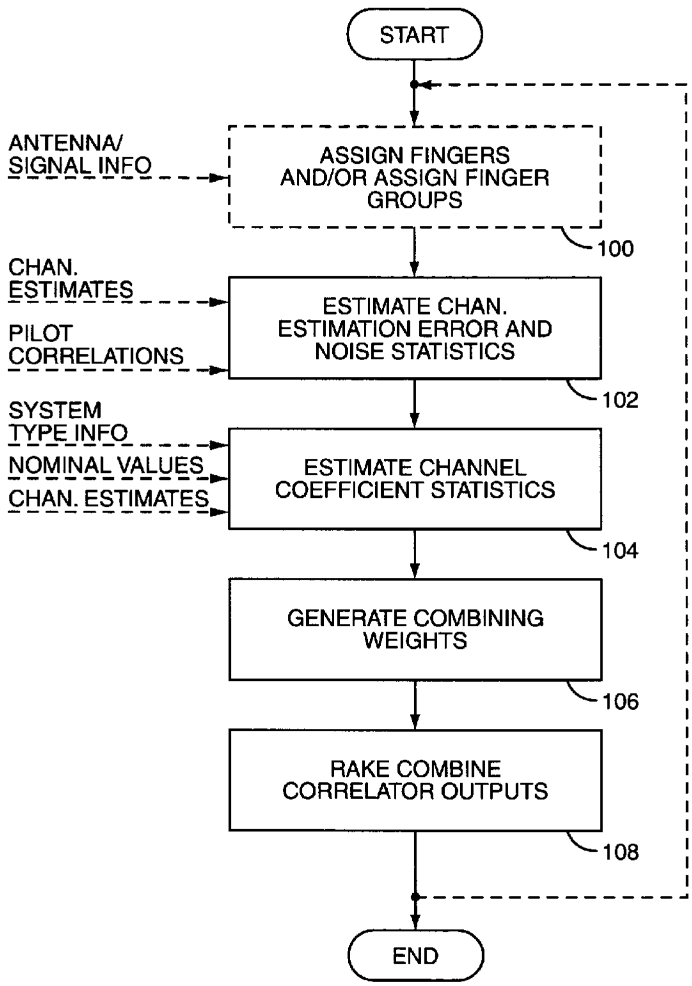
(57) **ABSTRACT**

A RAKE receiver circuit generates combining weights based on channel estimates and combining statistics that comprise channel coefficient statistics, noise statistics, and channel estimation error statistics. Together, these statistics incorporate the relationships in noise and channel estimation across two or more RAKE fingers, and thus improve combining weight generation. Exemplary determination of statistics comprises channel coefficient cross-correlations, noise cross-correlations, and channel estimation error cross-correlations. Determination of the statistics can be varied based on, for example, the assumption of default or nominal signal models. Further, statistics determination can be configured for different receive and transmit diversity scenarios, wherein combining statistics can be determined on a per diversity signal basis, or jointly for two or more diversity signals, or in a mixed separate/joint method wherein one or more statistics are determined on a per signal basis and one or more statistics are determined across the signals.



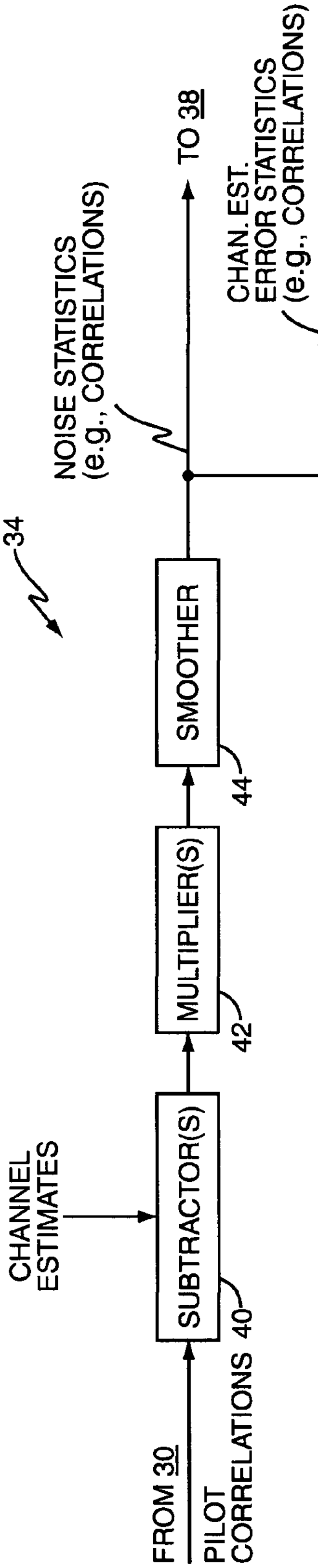

34
FROM 30
PILOT CORRELATIONS
CHANNEL ESTIMATES
SUBTRACTOR(S)
40
MULTIPLIER(S)
42
SMOOTHER
44
NOISE STATISTICS (e.g., CORRELATIONS)
TO 38
SCALER
46
CHAN. EST. ERROR STATISTICS (e.g., CORRELATIONS)
TO 38

FIG. 4

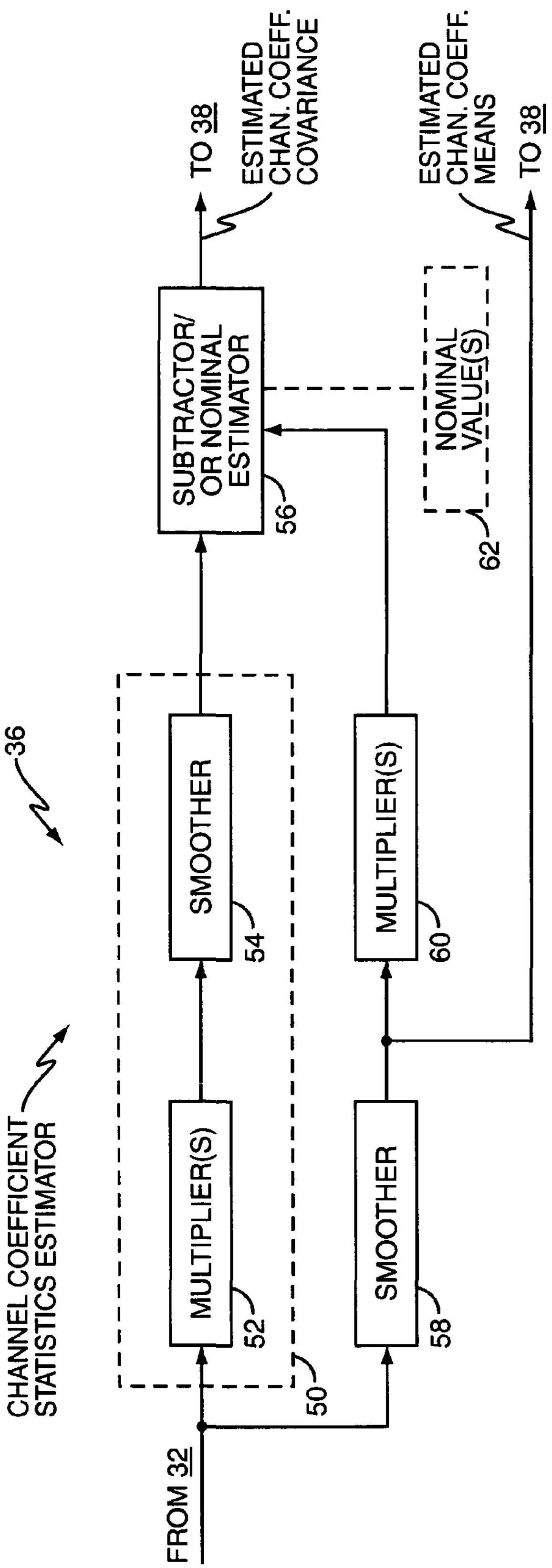

CHANNEL COEFFICIENT STATISTICS ESTIMATOR
36
FROM 32
50
MULTIPLIER(S)
52
SMOOTHER
54
SUBTRACTOR/ OR NOMINAL ESTIMATOR
56
ESTIMATED CHAN. COEFF. COVARIANCE
TO 38
SMOOTHER
58
MULTIPLIER(S)
60
NOMINAL VALUE(S)
62
ESTIMATED CHAN. COEFF. MEANS
TO 38

FIG. 5

METHOD AND APPARATUS FOR COMBINING WEIGHT COMPUTATION IN A DS-CDMA RAKE RECEIVER

BACKGROUND OF THE INVENTION

[0001] The present invention generally relates to RAKE receivers and particularly relates to the computation of the RAKE "combining weights" used in such receivers.

[0002] RAKE receivers represent a well-known approach to multipath reception, particularly in Direct Sequence Code Division Multiple Access (DS-CDMA) wireless communication systems. With multipath, a transmitted signal follows multiple propagation paths and the intended receiver thus receives multiple "versions" (images) of the transmitted signal, with each signal image generally suffering from different path delay, phase, and attenuation effects.

[0003] RAKE receivers exploit multipath by allocating each of two or more RAKE "fingers" to one of the incoming signal images. In that sense, then, each finger is tuned to a particular one of the multipath components of the incoming composite received signal and each finger thus receives its own version of the originally transmitted signal. By estimating the channel effects, e.g., phase and attenuation, and by properly accounting for the differences in path delays, the individual output from each finger may be RAKE combined with the outputs from the other fingers to provide a combined RAKE output signal whose signal-to-noise ratio (SNR) generally is improved by the summed contribution of each finger's despread output signal.

SUMMARY OF THE INVENTION

[0004] The present invention comprises a method and apparatus to generate RAKE receiver combining weights based on generating combining statistics. In an exemplary embodiment of the present invention, a method of generating RAKE combining weights comprises obtaining individual finger output signals by despreading a received signal in each of two or more RAKE fingers, generating channel estimates corresponding to the RAKE fingers, determining combining statistics comprising channel coefficient statistics, channel estimation error statistics, and noise statistics for the RAKE fingers, and computing RAKE combining weights for combining the individual finger output signals from the RAKE fingers into a RAKE combined signal based on the channel estimates and the combining statistics.

[0005] Determining combining statistics can comprise determining channel coefficient statistics, channel estimation error statistics, and noise statistics for the RAKE fingers based on estimating correlations of channel coefficients across the RAKE fingers, and determining channel estimation error correlations and noise correlations across the RAKE fingers. Determining combining statistics further can comprise estimating means of the channel coefficients for the RAKE fingers, and determining an estimation error covariance and a noise covariance across the RAKE fingers.

[0006] An exemplary RAKE receiver circuit according to the present invention comprises a RAKE processor circuit configured to obtain individual finger output signals by despreading a received signal in each of two or more RAKE fingers, generate channel estimates corresponding to the RAKE fingers, determine combining statistics comprising channel coefficient statistics, channel estimation error statistics, and noise statistics for the RAKE fingers, and compute RAKE combining weights for combining the individual finger output signals from the RAKE fingers into a RAKE combined signal based on the channel estimates and the combining statistics. The RAKE processor circuit can comprise a channel coefficient estimator configured to estimate channel coefficients for the RAKE fingers, a channel coefficient statistic estimator configured to estimate channel coefficient statistics, and a noise and error statistic estimator configured to estimate noise and channel estimation error statistics.

[0007] Exemplary RAKE receiver circuits according to the present invention can be implemented in a range of communication devices including, but not limited to, mobile terminals and wireless base stations for use in wireless communication networks. Further, the present invention may be used in a variety of network types, with exemplary networks including, but not limited to, Wideband CDMA (WCDMA) networks, IS-2000 networks, IS-95B networks, and essentially any other communication network that uses, or that might use, RAKE receivers.

[0008] In any of these embodiments, the exemplary RAKE receiver circuit can be implemented in hardware, software, or both. As such, an exemplary RAKE processor circuit comprises one or more microprocessors, such as one or more digital signal processors that are configured to execute program instructions stored in a computer readable medium embodying the above described exemplary method of combining weight generation, or variations thereof. Other signal processing elements can be used, such as Application Specific Integrated Circuits (ASICs) or Field Programmable Gate Arrays (FPGAs).

[0009] An exemplary RAKE receiver circuit can be configured to store, or otherwise have access to, nominal channel coefficient cross-correlation data based on, for example, one or more default fading correlation values.

[0010] Those skilled in the art should appreciate that the present invention is not limited to these broadly described embodiments. Indeed, the many additional features and advantages of the present invention will become apparent upon reading the following detailed description in conjunction with viewing the various exemplary drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] **FIG. 1** is a diagram of an exemplary wireless communication receiver according to the present invention.

[0012] **FIG. 2** is a diagram of an exemplary RAKE processor.

[0013] **FIG. 3** is a diagram of exemplary signal processing according to one or more embodiments of the present invention.

[0014] **FIG. 4** is a diagram of an exemplary estimator to estimate cross-finger noise correlations and channel estimation error correlations.

[0015] **FIG. 5** is a diagram of an exemplary estimator to estimate cross-finger channel coefficient correlations.

[0016] **FIG. 6** is a diagram of an exemplary combining weight generator.

[0017] **FIG. 7** is a diagram of exemplary logic implementing selective improved combining weight generation according to one or more embodiments of the present invention.

[0018] **FIG. 8** is a diagram of an exemplary transmit diversity embodiment.

[0019] **FIG. 9** is a diagram of an exemplary receive diversity embodiment.

[0020] **FIG. 10** is a diagram of an exemplary mobile terminal.

[0021] **FIG. 11** is a diagram of an exemplary radio base station.

DETAILED DESCRIPTION OF THE INVENTION

[0022] In discussing exemplary embodiments of the present invention in more detail, it should be understood from the outset that one or more embodiments of the present invention comprise signal processing methods that may be implemented in hardware using discrete or integrated circuits, in software as stored program instructions, or in some combination thereof. More generally, one or more embodiments of the present invention may be embodied in hardware and/or software (including firmware, resident software, micro-code, etc.).

[0023] Turning to the drawings, **FIG. 1** illustrates an exemplary receiver **10** according to one or more embodiments of the present invention. The exemplary receiver **10** comprises a radio front-end **12**, a RAKE receiver **14**, and additional, post-RAKE processing circuits **16**, such as a convolutional or turbo decoder. All or selected portions of the RAKE receiver **14** and additional processing circuits **16** may be integrated into a baseband processor, such as a Digital Signal Processor (DSP), microprocessor, Application Specific Integrated Circuit (ASIC), Field Programmable Gate Array, Complex Programmable Logic Device (CPLD), or other processing circuit.

[0024] Regardless of such implementation details, front-end **12** provides RAKE receiver **14** with one or more received signals, which may comprise streams of sample values obtained from wireless signals impinging on an antenna, or antennas, associated with the front-end **12**. Thus, an exemplary front-end **12** includes amplifiers, filters, mixers, and digitizers as needed to produce a sampled signal suitable for processing by RAKE receiver **14**. The received signal samples, r(t), provided to RAKE receiver **14** may comprise samples from a composite received signal that includes one or more signal images arising from, for example, multipath propagation between receiver **10** and a remote transmitter (not shown).

[0025] Further, the received signal, r(t), may include samples from multiple transmit signals (transmit diversity) and/or samples from multiple receive signals obtained from, for example, two or more receive antennas used for receive diversity. In some embodiments, signals associated with different antennas can be routed into RAKE receiver **14** for individual, joint, or mixed processing, i.e., some processing done per signal and some done jointly.

[0026] In any case, an exemplary RAKE receiver **14** comprises a plurality of correlators (fingers) **20**, a RAKE processor **22**, and a combining circuit (combiner) **24**. Each finger **20** despreads its input signal to produce an individual finger output signal. Combiner **24** combines the individual finger output signals according to RAKE combining weights to generate a RAKE combined signal. Fingers **20** and combining circuit **24** operate under control of RAKE processor **22**.

[0027] As is understood in the art, each finger **20** can be time-aligned to despread its input signal at a desired arrival time offset, e.g., at an assigned "path" delay. Thus, in exemplary operation, RAKE receiver **14** aligns each of one or more "active" fingers **20** at least roughly with a desired signal image. (Some fingers **20** may be aligned with interference images as well.) As noted, the despread signal obtained in each finger **20** is multiplied with combining weights in association with being combined in combiner **24** to generate the RAKE combined signal. Such operation allows the RAKE receiver **14** to benefit from multipath reception by despreading multiple signal images in one or more received signals and then combining the individual despread signal outputs from each finger **20** in combiner **24**.

[0028] In traditional RAKE receivers, RAKE combining weights correspond to "channel estimates" that model the propagation path of the signal image being despread by a particular finger **20**. However, according to the present invention, RAKE combining weights are generated in consideration of several statistics related to despreading operations across the fingers **20**. (When referring to more than one finger **20** herein, it should be understood that such reference can include all fingers.) More particularly, in an exemplary embodiment of the present invention, the RAKE processor **22** generates, or controls the generation of, combining weights that are based at least in part, on channel coefficient statistics, channel estimation error statistics, and noise statistics.

[0029] For example, RAKE processor **22** can be configured to generate estimates of channel coefficient cross-correlations for two or more fingers **20** using, for example, channel measurements obtained from a received pilot signal, e.g., received pilot symbols. Among other information, cross-correlations in the channel coefficients can compensate for correlations in signal fading or correlations in other reception phenomenon affecting all or some subset of the fingers **20**.

[0030] RAKE processor **22** further can be configured to generate estimates of channel estimation error cross-correlation for two or more fingers **20** using, for example, despread pilot correlations. In one embodiment, differences between pilot correlations and corresponding channel estimates are processed and smoothed to generate noise cross-correlations for a set of fingers **20**, and the noise cross-correlations are scaled according to a smoothing factor, for example, to obtain the channel estimation error cross-correlations.

[0031] In other embodiments, the channel coefficient statistics include estimates of the statistical means of channel coefficients for each finger **20** and the cross-finger relationships for estimation error and noise are expressed in terms of error covariance and noise covariance. Indeed, as explained in greater detail later herein, RAKE processor **22** can be configured to use default or nominal values that can include the assumption of a zero mean, in which case

cross-finger estimation error and noise relationships are expressed in terms of covariances with an assumed zero mean.

[0032] Supporting the above operations, FIG. 2 illustrates an exemplary RAKE processor 22 comprising pilot correlators 30, a channel estimator 32, an estimation error and noise statistics estimator 34, a channel coefficient statistics estimator 36, and a combining weight generator 38. In one aspect of its operation, performance of RAKE receiver 14 is improved by improving the combining weights. As noted, an exemplary combining weight generation method accounts for channel coefficient statistics, noise statistics, and channel estimation error statistics for two or more fingers 20.

[0033] FIG. 3 illustrates exemplary processing logic that can be implemented in RAKE receiver 14 in, for example, a programmed logic circuit executing stored program instructions, or in a dedicated logic circuit. Regardless, exemplary processing begins with the assignment of two or more fingers 20 to a given received signal (Step 100). For example, RAKE receiver 14 may assign one finger 20 to each of the three strongest signal images comprising received signal r(t). Of course, it may assign different groups of fingers 20 to different signals (e.g., from different transmit and/or receive antennas, etc.). Regardless, for a given group of fingers 20, RAKE receiver 14 estimates channel coefficient statistics, channel estimation error statistics, and noise statistics for the group of fingers 20 (Steps 102 and 104). RAKE receiver 14 may use channel estimates and pilot correlations (or data channel derived values) to determine estimation error and noise correlations, and additionally may use system type information and/or stored nominal fading statistics to estimate channel coefficient statistics such as cross-finger fading correlations.

[0034] RAKE receiver 14 uses the estimated statistics in generating the finger combining weights for the group (or groups of fingers 20) (Step 106), and then uses the generated combining weights to RAKE combine the finger outputs for the group (or groups) of fingers 20 (Step 108). Thus, RAKE receiver 14 outputs a RAKE combined signal (or signals) for subsequent processing, wherein the RAKE combined output signal is compensated using the aforementioned statistics. Such compensation improves receiver performance by accounting for relationships in noise, estimation error, and channel coefficients for the group of fingers 20.

[0035] To better understand the above exemplary processing, one must first understand that, in general, a receiver's performance is sensitive to the RAKE combining weights used. In the presence of white noise, a RAKE receiver theoretically should use combining weights that correspond to the channel coefficients for the radio channel. That is, if w denotes the combining weights and ĉ denotes the estimated channel coefficients, then

$$w=\hat{c}. \quad (1)$$

[0036] When interference is better modeled as colored noise, the RAKE combining theoretically should correspond to the product of a noise covariance matrix inverse and a vector of estimated channel coefficients, such as:

$$w=R_n^{-1}\hat{c}, \quad (2)$$

[0037] where R_n denotes a noise covariance matrix and ĉ denotes the estimated channel coefficient vector. Generalized RAKE receivers (GRAKE) use a combining weight form like that shown in Eq. (2), wherein the noise covariance is replaced with an estimated quantity.

[0038] In some respects, RAKE receiver 14 may be regarded as an extension of GRAKE operation in that its combining weights take on a structure similar to that given above. However, according to the present invention, exemplary combining weight generation accounts for statistics not contemplated in existing architectures.

[0039] In more detail, the exemplary channel estimator 32 generates channel estimates for each active finger 20. However, each such estimate is an imperfect representation of the corresponding actual propagation channel, which means that to a greater or lesser extent, each channel estimate includes some amount of estimation error. In one sense, the estimation error may be thought of as estimation "noise" that may be statistically related across two or more fingers 20. Thus, by estimating statistics for the estimation errors, e.g., estimating error cross-correlations for two or more fingers 20, and using such statistics in combining weight generation, the RAKE combining operations may be improved. Similarly, RAKE combining may be improved by considering additional statistics for the channel coefficients and noise as part of combining weight generation.

[0040] In examining such operations, it may be helpful to recognize that an ultimate goal of RAKE-based demodulators is to provide a log-likelihood ratio for each transmitted information bit in the received signal. One can model the vector of despread values as,

$$x=cs+n, \quad (3)$$

[0041] where s is the symbol transmitted (e.g., BPSK, QPSK, 16 QAM) and n is the composite noise on the despread values. The noise may be modeled as being Gaussian with zero mean and covariance R_n. Similarly, one can model the channel coefficient as Gaussian with covariance R_c. The coefficient can be either zero mean (Rayleigh fading) or have a mean value $\bar{c}$ (Rice fading). The mean and covariance are examples of channel coefficient statistics that can be used in generating the combining weights. As will be detailed later, RAKE receiver 14 can be configured to use stored (default) statistical information for one or more fading scenarios. Receiver 14 can use such models on a selective basis, or may fix its selection of a particular fading model based on system type, e.g., high mobility or low mobility system types. However, in at least one embodiment, receiver 14 dynamically generates (estimates) the channel coefficient statistics used in combining weight generation.

[0042] In any case, the channel coefficient vector c can be estimated by correlating to pilot symbols, a pilot channel, and/or data symbols. Modulation, if any, may be removed from pilot signal/symbol (or training sequence) correlations, and the results smoothed over time. Note that if data symbols received in a data channel signal are used for channel estimation, receiver 14 can be configured to implement some form of decision feedback to remove the symbol modulation. Regardless, RAKE receiver 14 obtains a vector of channel measurements y, which can be modeled as

$$y=c+e, \quad (4)$$

[0043] where e models estimation error on the channel measurements. The values in channel measurement vector y may be considered as initial channel estimates.

[0044] Determination of channel estimation error statistics can be implemented as a determination of cross-correlations for two or more fingers **20**. Such cross-correlations can be obtained by modeling the errors as Gaussian with zero mean and covariance R_e. Because the channel measurements experience noise with the same statistical properties as the despread values obtained from the data channel signal, the covariance matrices—i.e., the channel estimation error covariance versus the traffic channel noise covariance—can be related as follows:

$$R_e=(1/K)R_n, \tag{5}$$

[0045] where K is a factor related to the amount of smoothing used in forming the channel estimates. For example, suppose channel estimates are obtained by averaging N_p pilot despread values, then $K=N_p$. Thus, RAKE receiver **14** may estimate the covariance of the channel estimate error based on scaling the covariance of the received traffic signal noise.

[0046] While the examples given will focus on estimating channel estimate error correlations by scaling noise correlation estimates, the present invention can use other forms of noise and error correlation estimation. For example, noise correlations can be estimated using data despread values. Outer products of traffic data despread vectors can be averaged to obtain a traffic correlation matrix. An estimate of the channel coefficient correlation matrix can then be subtracted to obtain an estimate of the noise correlation matrix.

[0047] A first example considers the general case of Rice fading, in which the true channel coefficients are modeled as having mean $\bar{c}$ and covariance R_c. It can be shown that when noise in the channel measurements is accounted for in determining the likelihood of bits in a symbol s received in r(t), the combining weights should have the form

$$w=A^{-1}b \tag{6}$$

where

$$A=R_n+R_e(R_c+R_e)^{-1}R_c=R_n+(1/K)R_n(R_c+(1/K)R_n)^{-1}R_c, \tag{7}$$

$$b=R_c(R_c+R_e)^{-1}y+R_e(R_c+R_e)^{-1}\bar{c},$$

[0048] which can be expressed as,

$$b=R_c(R_c+(1/K)R_n)^{-1}y+(1/K)R_n(R_c+(1/K)R_n)^{-1}\bar{c}. \tag{8}$$

[0049] It may be noted that the above formulations are reminiscent of the GRAKE combining weights, but with several distinctions, including these items:

[0050] 1. The channel coefficient measurement vector y is replaced by a scaled version b, which is scaled as a function of covariances of the channel coefficient process and the noise process. This has the form of a minimum mean square error (MMSE) channel estimator.

[0051] 2. A term is added to the scaled channel coefficient measurement vector that depends on the mean of the channel estimation coefficient vector. In one or more exemplary embodiments the term may be omitted, such as where the channel is assumed to be Rayleigh fading.

[0052] 3. The noise covariance is augmented by a second term that depends on the channel coefficient statistics and the channel estimation error statistics, e.g., a term that depends on covariances of the channel coefficients and the channel estimation errors.

[0053] Thus, in one or more exemplary embodiments of the present invention, the covariance matrices are estimated at least in part from the received signal r(t) and used by RAKE receiver **14** to form the combining weights as described above.

[0054] One method of simplifying combining weight generation assumes that the channel coefficient mean is zero. This is a reasonable assumption in many cases and provides a simplification of the weights by changing the b vector to,

$$b=R_c(R_c+R_e)^{-1}y=R_c(R_c+(1/K)R_n)^{-1}y, \tag{9}$$

[0055] With the above simplification, the channel coefficient covariance R_c is equal to the channel coefficient correlation matrix. This simplifying approach may work well even if the true channel coefficient(s) have non-zero mean.

[0056] The noise covariance may be estimated by despreading random sequences. In an exemplary embodiment, noise covariance is estimated by despreading a pilot channel or pilot symbols and then forming channel coefficient estimates in the channel estimator **32**.

[0057] The channel estimates are provided to the estimation error and noise statistics estimator **34**, which subtracts the estimates from their corresponding despread values to generate noise samples. Noise samples corresponding to different pairs of fingers **20**, including pairing a particular finger **20** with itself, are multiplied together (after conjugating one of the two complex samples) and smoothed over time to generate cross-finger noise correlation values. As the noise samples are assumed to have zero mean, these noise correlation values correspond to noise covariance values. In an exemplary embodiment of the present invention, the noise correlations are scaled to form channel estimation error correlations.

[0058] **FIG. 4** illustrates an exemplary embodiment of the estimation error and noise statistics estimator **34**. The illustrated estimation error and noise statistics estimator **34** comprises subtractors **40**, multipliers **42**, and a smoother **44**. In exemplary operation, estimator **34** receives channel estimates from channel estimator **32** and pilot correlations from pilot correlators **30**. Note, to handle pilot symbol modulation, the pilot correlators **30** produce pilot correlations with modulation removed. Thus, subtractors **40** obtain differences between the pilot correlations and the channel estimates, which amounts to subtracting estimated pilot values from the actual pilot correlations to obtain noise values. These noise values flow into the multipliers **42**, and the output of multipliers **42** feed into smoother **44**. In turn, then, smoother **44** provides the combining weight generator **38** with smoothed estimates of noise correlations across some or all of the fingers **20**. Scalar **46** is, in an exemplary embodiment, configured to scale the noise correlations by 1/K to generate the channel estimation error correlations.

[0059] In another exemplary embodiment, correlations between despread values are based on using pilot and/or data despread values. This gives the sum of the noise and signal correlations. The signal correlation is also estimated, as described below. Then, the signal correlation is subtracted from the despread value correlations to obtain the noise correlation.

[0060] One or more other exemplary embodiments of RAKE receiver **14** use prior knowledge of the noise. For example, in some situations, such as the uplink, it can be assumed that the noise is white. As such, RAKE receiver **14** may determine the noise correlation values as a function of the receive filter response of receiver **10** and the noise power. Specifically, the noise correlation is the product of the noise power and the receive filter autocorrelation function. The latter can usually be approximated with the transmit chip pulse shape autocorrelation, which is known. Thus, in this case, only the noise power needs to be estimated, which can be done by averaging the noise power estimates from each finger **20**.

[0061] Turning to estimation of channel coefficient statistics, **FIG. 5** illustrates an exemplary embodiment of the channel coefficient statistics estimator **36**. The illustrated estimator **36** comprises correlation estimator **50** that operates on channel estimates from channel estimator **32**, and which comprises multipliers **52** and a smoother **54**. Estimator **36** further comprises a coefficient means estimator comprising smoother **58** and multipliers **60**.

[0062] Thus, the output of smoother **54** comprises channel coefficient estimate correlations, in a Rayleigh fading model where the mean is zero, the output comprises covariance estimates. The output of multiplier **60** comprises an estimate of the means of the channel coefficients. With this arrangement, then, subtractor/nominal estimator **56** included in estimator **36** provides a covariance output based on subtracting means from channel coefficient cross-correlations. Alternatively, or additionally, subtractor/nominal estimator **56** can use nominal values stored in a memory **62**. For example, a nominal fading correlation across antennas of 0.7 can be used to construct a channel coefficient correlation matrix. The value 0.7 can be used or can be replaced with an estimated antenna correlation parameter. Additionally, subtractor/nominal estimator **56** may remove an estimate of the estimation error correlation matrix to convert the channel estimate covariance into the channel coefficient covariance.

[0063] In operation, estimator **36** generates channel coefficient statistics based on, for example, channel estimates, denoted as y_k, corresponding to different times (index k), as provided by the channel estimator **32**. Either smoothed or unsmoothed channel estimates from channel estimator **32** may be used. These channel estimates are used to estimate the channel estimate cross-correlation matrix Q by forming outer products of the channel estimate vectors (products of coefficients with the conjugate of other coefficients) and smoothing. For example, with exponential smoothing, the correlation matrix would be formed using

$$\hat{Q}_c(k)=\lambda\hat{Q}_c(k-1)+(1-\lambda)y_k y_k^H. \tag{10}$$

[0064] For the embodiments based on Rayleigh fading,

$$\hat{R}_c(k)=\hat{Q}_c(k)-\hat{R}_e(k). \tag{11}$$

[0065] Eq. **11** can be approximated without bias removal as,

$$\hat{R}_c(k)=\hat{Q}_c(k) \tag{12}$$

[0066] Further processing would not be needed, as the mean is assumed to be zero ($\hat{c}$=0). Thus, the channel coefficient correlation output may be taken from the correlation estimator **50**.

[0067] With Rice fading, the non-zero mean can be estimated by exponentially smoothing y. Thus, the channel estimates would be smoothed using, for example smoother **58**, which may operate as an exponential smoother, giving a mean estimate of

$$\hat{\bar{c}}(k)=\lambda\hat{\bar{c}}(k-1)+y_k. \tag{13}$$

[0068] Then, the mean estimate and correlation matrix estimate may be used to determine the covariance according to

$$\hat{R}_c(k)=Q_c(k)-\hat{\bar{c}}\hat{\bar{c}}^H-\hat{R}_e(k). \tag{14}$$

[0069] An outer product of the mean estimate vector may be formed using multipliers **60**. The resulting outer product matrix may then subtracted from the correlation matrix using subtractor/estimator **56** to obtain a covariance matrix as the cross-finger fading correlation output to be used by combining weight generator **38**. Due to the Hermitian property of the correlation and covariance matrices, only the diagonal and one triangle (upper or lower) need to be estimated and stored.

[0070] Note that subtractor/estimator **56** may operate on a selective basis under control of RAKE processor **22**, for example, and thus may provide default channel coefficient correlations as its output, or provide generated values based on the received signal, based on the receiver filter pulse shape, etc. Regardless, estimator **36** provides combining weight generator **38** with channel coefficient statistics, such as coefficient means and/or estimates of channel coefficient correlations across two or more fingers **20** of the RAKE receiver **14**.

[0071] Together, estimators **34** and **36** together provide combining weight generator **38** with estimates of channel coefficient, estimation error and noise statistics relating a pair of fingers **20**, a group of fingers **20**, etc. Indeed, such statistics may be generated independently for different groups of fingers **20**, e.g., correlations across a first group of fingers **20**, and separately determined correlations across another group of fingers **20**, etc. For example, each group could correspond to a different base station signal in soft handover in the downlink. Another example is grouping fingers from different receive antennas that correspond to the same path delay.

[0072] In any case, **FIG. 6** illustrates an exemplary embodiment of the combining weight generator **38**, which comprises a weight solver **64**, a vector generator **66**, and a matrix generator **68**. It should be understood that these elements represent functional but not necessarily separate physical elements of combining weight generator **38**, and that these functions may be performed together in the RAKE processor **22**, which itself may be implemented as part of a baseband signal processor, or other logic circuit, e.g., a microprocessor executing a stored computer program.

[0073] With the illustrated implementation, solver **64** outputs the desired RAKE combining weights based on the b

generating channel estimates corresponding to the RAKE fingers;

determining combining statistics comprising channel coefficient statistics, channel estimation error statistics, and noise statistics for the RAKE fingers; and

computing RAKE combining weights for combining the individual finger output signals from the RAKE fingers into a RAKE combined signal based on the channel estimates and the combining statistics.

2. The method of claim 1, wherein determining combining statistics comprising channel coefficient statistics, channel estimation error statistics, and noise statistics for the RAKE fingers comprises estimating correlations of channel coefficients across the RAKE fingers, and determining estimation error and noise correlations across the RAKE fingers.

3. The method of claim 1, wherein determining combining statistics comprising channel coefficient statistics, channel estimation error statistics, and noise statistics for the RAKE fingers comprises estimating means of the channel coefficients for the RAKE fingers, and determining estimation error covariance and noise covariance across the RAKE fingers.

4. The method of claim 3, wherein determining combining statistics further comprises determining channel coefficient covariance across the RAKE fingers.

5. The method of claim 1, wherein generating channel estimates corresponding to the RAKE fingers comprises smoothing despread pilot values.

6. The method of claim 5, wherein determining noise statistics comprises determining noise cross-correlation based on the despread pilot values and scaling the noise cross-correlation based on a smoothing factor to obtain an estimation error cross-correlation as the channel estimation error statistics.

7. The method of claim 1, wherein generating channel estimates corresponding to the RAKE fingers comprises generating channel estimates from a received pilot signal, and wherein determining noise statistics for the RAKE fingers comprises generating a noise cross-correlation matrix from the received pilot signal.

8. The method of claim 1, wherein computing RAKE combining weights for combining the individual finger output signals from the RAKE fingers into a RAKE combined signal based on the channel estimates and the combining statistics comprises:

scaling a channel coefficient measurement vector based on channel coefficient covariance and estimation error cross-correlation determined for the RAKE fingers;

adding a term to the scaled channel coefficient measurement vector based on means of the channel coefficients determined for the RAKE fingers; and

augmenting a noise covariance matrix representing the noise covariance based on the channel coefficient covariance and an estimation error covariance determined for the RAKE fingers.

9. The method of claim 1, wherein computing RAKE combining weights for combining the individual finger output signals from the RAKE fingers into a RAKE combined signal based on the channel estimates and the combining statistics comprises:

scaling a channel coefficient measurement vector based on channel coefficient cross-correlation and estimation error cross-correlation determined for the RAKE fingers; and

using the scaled channel coefficient measurement vector and a noise correlation matrix determined for the RAKE fingers to solve for the combining weights.

10. The method of claim 1, wherein determining channel coefficient statistics comprises determining means of the channel coefficients based on smoothing the channel estimates.

11. The method of claim 10, wherein smoothing the channel estimates comprises smoothing values in a channel estimate coefficient vector according to an exponential smoothing filter.

12. The method of claim 1, wherein determining channel coefficient statistics comprises determining channel coefficient statistics across the RAKE fingers such that combining weight generation is compensated for correlations in channel coefficients across the RAKE fingers.

13. The method of claim 12, further comprising determining the channel coefficient statistics based on nominal channel coefficient statistics corresponding to one or more default fading models.

14. The method of claim 1, further comprising receiving signals on two or more receiver antennas.

15. The method of claim 14, wherein determining combining statistics comprises determining noise and estimation error correlations and channel coefficient correlations jointly across the receiver antennas.

16. The method of claim 14, wherein determining combining statistics comprises determining noise and estimation error correlations separately for each receiver antenna and determining channel coefficient correlations jointly across the receiver antennas.

17. The method of claim 14, further comprising assigning a set of RAKE fingers to a received signal from each receiver antenna and determining the combining statistics separately for each set of RAKE fingers.

18. The method of claim 1, further comprising receiving signals from two or more transmit antennas.

19. The method of claim 18, wherein determining combining statistics comprises determining noise and estimation error correlations and channel coefficient correlations jointly across the transmit antennas.

20. The method of claim 18, wherein determining combining statistics comprises determining noise and estimation error correlations separately for each transmit antenna and determining channel coefficient correlations jointly across the transmit antennas.

21. The method of claim 18, further comprising assigning a set of RAKE fingers to a received signal corresponding to each transmit antenna and determining the combining statistics separately for each set of RAKE fingers.

22. The method of claim 1, wherein computing RAKE combining weights for combining the individual finger output signals from the RAKE fingers into a RAKE combined signal based on the channel estimates and the combining statistics comprises selectively computing the combining weights based on the channel estimates and the combining statistics.

23. The method of claim 22, wherein selectively computing the combining weights based on the channel estimates and the combining statistics comprises using the combining

statistics to compute the combining weights in a first mode, and using a subset of the combining statistics in a second mode.

24. The method of claim 23, further comprising selecting between the first and second modes based on determining a normalized fading correlation.

25. A RAKE receiver circuit comprising:

a RAKE processor circuit configured to

obtain individual finger output signals by despreading a received signal in each of two or more RAKE fingers;

generate channel estimates corresponding to the RAKE fingers;

determine combining statistics comprising channel coefficient statistics, channel estimation error statistics, and noise statistics for the RAKE fingers; and

compute RAKE combining weights for combining the individual finger output signals from the RAKE fingers into a RAKE combined signal based on the channel estimates and the combining statistics.

26. The circuit of claim 25, wherein the RAKE processor circuit comprises a channel coefficient estimator configured to estimate channel coefficients for the RAKE fingers, a channel coefficient statistic estimator configured to estimate channel coefficient statistics, and a noise and error statistic estimator configured to estimate noise and channel estimation error statistics.

27. The circuit of claim 26, wherein the RAKE processor circuit further comprises a combining weight generator to compute the RAKE combining weights.

28. The circuit of claim 25, wherein the RAKE processor circuit is configured to determine combining statistics comprising channel coefficient statistics, channel estimation error statistics, and noise statistics for the RAKE fingers by estimating correlations of channel coefficients across the RAKE fingers, and determining estimation error and noise correlations across the RAKE fingers.

29. The circuit of claim 25, wherein the RAKE processor circuit is configured to determine combining statistics comprising channel coefficient statistics, channel estimation error statistics, and noise statistics for the RAKE fingers by estimating means of the channel coefficients for the RAKE fingers, and determining estimation error covariance and noise covariance across the RAKE fingers.

30. The circuit of claim 29, wherein the RAKE processor circuit is configured to determine combining statistics further by determining channel coefficient covariance across the RAKE fingers.

31. The circuit of claim 25, wherein the RAKE processor circuit is configured to generate channel estimates corresponding to the RAKE fingers by smoothing despread pilot values.

32. The circuit of claim 31, wherein the RAKE processor circuit is configured to determine noise statistics comprises determining noise cross-correlation based on the despread pilot values and to scale the noise cross-correlation based on a smoothing factor to obtain an estimation error cross-correlation as the channel estimation error statistics.

33. The circuit of claim 25, wherein the RAKE processor circuit is configured to generate channel estimates corresponding to the RAKE fingers by generating channel estimates from a received pilot signal, and wherein the RAKE processor circuit is configured to determine noise statistics for the RAKE fingers by generating a noise cross-correlation matrix from the received pilot signal.

34. The circuit of claim 25, wherein the RAKE processor circuit is configured to compute RAKE combining weights for combining the individual finger output signals from the RAKE fingers into a RAKE combined signal based on the channel estimates and the combining statistics by:

scaling a channel coefficient measurement vector based on channel coefficient covariance and estimation error cross-correlation determined for the RAKE fingers;

adding a term to the scaled channel coefficient measurement vector based on means of the channel coefficients determined for the RAKE fingers; and

augmenting a noise covariance matrix representing the noise covariance based on the channel coefficient covariance and an estimation error covariance determined for the RAKE fingers.

35. The circuit of claim 25, wherein the RAKE processor circuit is configured to compute RAKE combining weights for combining the individual finger output signals from the RAKE fingers into a RAKE combined signal based on the channel estimates and the combining statistics by:

scaling a channel coefficient measurement vector based on channel coefficient and estimation error cross-correlation determined for the RAKE fingers; and

using the scaled channel coefficient measurement vector and a noise correlation matrix determined for the RAKE fingers to solve for the combining weights.

36. The circuit of claim 25, wherein the RAKE processor circuit is configured to determine channel coefficient statistics by determining means of the channel coefficients based on smoothing the channel estimates.

37. The circuit of claim 36, wherein the RAKE processor circuit is configured to smooth the channel estimates by smoothing values in a channel estimate coefficient vector according to an exponential smoothing filter.

38. The circuit of claim 25, wherein the RAKE processor circuit is configured to determine channel coefficient statistics by determining channel coefficient statistics across the RAKE fingers such that combining weight generation is compensated for correlations in channel coefficients across the RAKE fingers.

39. The circuit of claim 38, wherein the RAKE processor circuit is configured to determine the channel coefficient statistics based on nominal channel coefficient statistics corresponding to one or more default fading models.

40. The circuit of claim 39, further comprising a memory circuit to store data corresponding to the one or more default fading models.

41. The circuit of claim 25, wherein the RAKE processor circuit is configured to process signals from two or more receiver antennas.

42. The circuit of claim 41, wherein the RAKE processor circuit is configured to determine combining statistics by determining noise and estimation error correlations and channel coefficient correlations jointly across the receiver antennas.

43. The circuit of claim 41, wherein the RAKE processor circuit is configured to determine combining statistics by determining noise and estimation error correlations sepa-

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(54) **METHOD AND DEVICE FOR MULTI-USER CHANNEL ESTIMATION**

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(List continued on next page.)

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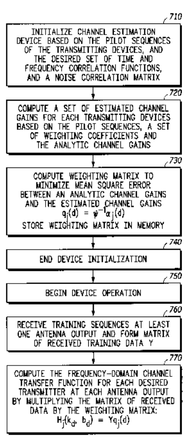
(57) **ABSTRACT**

The invention computes frequency-domain channel gains by compiling a set of estimated channel gains as a function of pilot sequences, a set of analytical channel gains variables, and a set of weighting coefficients variables. A plurality of weighting coefficients are computed as a function of time and frequency correlation functions, a noise correlation matrix, and pilot sequences. A weighting matrix is computed from the weighting coefficients. After receiving a training sequence from at least one transmitter, a received data matrix is computed from the training sequence. The weighting matrix and the received data matrix are used to compute the frequency-domain channel gains. The invention also provides a method for reducing the computational complexity of estimating the time and frequency response of at least one desired signal received by at least one antenna. Also, the time and frequency response of at least one desired signal received by at least one antenna can be both interpolated and predicted with the present invention.

26 Claims, 10 Drawing Sheets



700

where H_j is a M by P matrix of analytic channel gains (which act as variables to hold the values of the true channel gains) for the j^{th} user at the M antennas and the P pilot symbols:

$$H_j=[H_j(k_1,b_1)\ H_j(k_2,b_2)\ \ldots\ H_j(k_P,b_P)], \tag{9}$$

In Equation (8), N is the M by P matrix of noise samples on the M antennas at the P pilot symbols; s_j is a P by 1 vector of pilot symbols for the j^{th} SDMA user, and the diag(x) operator produces a square matrix having all zeros except for the main diagonal, which contains the vector argument. By making use of Equation (8), the estimate for the channel gains as expressed in Equation (4) can now be written as

$$\hat{H}_j(k_d, b_d) = \left[\sum_{j=1}^{J}[H_j diag(s_j)] + N\right]q_j(d),\ d = 1\ \ldots\ D \tag{10}$$

This equation basically states that the set of estimated channel gains is a function of the set of analytic channel gains, the known pilot sequences transmitted by the J transmitting devices, the primary weighting coefficients, and the noise signals received on the receiving antennas.

After making use of Equation (10), Equation (7) can be written as:

$$MSE(j,d) = E\left[\left\|H_j(k_d, b_d) - \left(\sum_{j=1}^{J}[H_j diag(s_j)] + N\right)q_j(d)\right\|^2\right] \tag{11}$$

This equation states that the mean square error is a function of the analytic channel gains (also known as the true channel gains), the pilot sequences, the received noise samples, and the primary weighting coefficients. At this point, the problem can be equivalently expressed as the following minimization problem:

$$\min_{\substack{q_j(d)\\ j=1\ \ldots\ J\\ d=1\ \ldots\ D}} E\left[\left\|H_j(k_d, b_d) - \left(\sum_{j=1}^{J}[H_j diag(s_j)] + N\right)q_j(d)\right\|^2\right] \tag{12}$$

Given Equation (11), Equation (12) states that the set of primary weighting coefficients $q_j(d)$ is computed to minimize the mean square error for the simulated error signal.

The value of $q_j(d)$ that minimizes Equation (11) can be shown to be:

$$q_j(d)=\Psi^{-1}\alpha_j(d) \tag{13}$$

and the MMSE channel estimator is then given by

$$\hat{H}_j(k_d,b_d)=Y\Psi^{-1}\alpha_j(d) \tag{14}$$

where

$$\alpha_j(d)=\mathrm{diag}(s^*_j)E\{H_j^H H_j(k_d,b_d)\} \tag{15}$$

and

$$\Psi = \sum_{n=1}^{J}[diag(s_n^*)E\{H_n^H H_n\}diag(s_n)] + MR_{nn} \tag{16}$$

In an embodiment of the present invention, Equation (13), the set of primary weighting coefficients, will be computed when the receiver is initialized before the receiver receives any information bursts.

In the above equations, $E\{H_j^H H_j(k_d,b_d)\}$ is a P by 1 vector whose i^{th} element is the correlation between the channel gain at the i^{th} pilot symbol (located at subcarrier f_i and baud t_i) and the channel at the d^{th} data symbol (located at subcarrier k_d and time b_d). Also, $E\{H_j^H H_j\}$ is a P×P matrix whose $(i,j)^{th}$ element is the correlation between the channel at the i^{th} pilot symbol (located at subcarrier f_i and baud t_i) and the channel at the j^{th} pilot symbol (located at subcarrier f_j and baud t_j). Furthermore, R_{nn} is the P×P noise correlation matrix, which in a preferred embodiment is equal to $\sigma^2 I_p$, where σ^2 is the noise power on a receive antenna element. It can be shown that:

$$E\{H_j^H(k+f,b+n)H_j(k,b)\}=Mr_F(f)r_T(n) \tag{17}$$

where $r_F(f)$ is the channel correlation across frequency, which is determined by the nature of the delay-spread profile of the propagation channel. Also, $r_T(n)$ is the channel correlation across time, which is determined by the Doppler profile of the propagation channel. If an estimate of the channel gain is required at a point within the information burst occupied by a pilot symbol, then the above analysis is valid provided the correlation functions properly reflect the correlation between the point where the channel gain is required and all the pilot symbol locations within the burst.

The above analysis, as expressed in equations (8) and (9), is establishing a mathematical expression of the true channel gains (the matrix H_j and its components therein), which are called the "analytic channel gains." The above analysis also establishes, through equations (3) and (4), an estimate of the channel gains, called the "estimated channel gains," which is mathematically expressed in terms of the analytic channel gains, the set of primary weighting coefficients $q_j(d)$, and the pilot sequences through equations (10). The above analysis implicitly establishes through equation (7), an error signal between the estimated channel gains and the analytic channel gains, which is equal to $H_j(k_d,b_d)-\hat{H}_j(k_d,b_d)$. This error signal is a function of the primary weighting coefficients, the pilot sequences, and the analytic channel gains as shown by using Equation (10) in Equation (7). The analysis then solves for the primary weighting coefficients to minimize the power of the error signal, or equivalently, to minimize the mean square error, as shown in Equations (11) and (12). An estimate for the channel gains is then found by multiplying the matrix containing the data received at the pilot symbols by the primary weighting coefficients as shown in Equations (3), (4), (13), and (14).

The performance of this MMSE channel estimator is therefore related to the choice of both time and frequency channel correlation functions in the equations for the estimated channel gains. First the choice of the frequency correlation function, $r_F(f)$, will be discussed. Afterwards, the choice of the time correlation function, $r_T(n)$, will be discussed. One possible choice for the frequency correlation function is a sampled flat delay spread profile with some maximum number of time-domain samples, L, where L is an integer. The complex conjugate of the associated frequency-domain correlation function is the K point DFT of a square window of amplitude 1/L and length L. In equation form this is given as (for f=0 . . . K−1):

$$r_F(f) = \left(\frac{1}{L}\right)e^{j\pi(L-1)f/K}\frac{\sin\pi fL/K}{\sin\pi f/K} \tag{18}$$

The drawback of this correlation function is that it assumes that the channel gains at the subcarriers around k=1 are highly correlated with the channel gains at the subcar-

estimator gives estimates. It can also be used to predict the channel at future or past times.

The third embodiment of the reduced complexity estimator is a combination of the first and second ways. This is done by using the $Q_j(b)$ of Equation (44) in Equation (48). Here $Z_{j,l}$ is referred to as the reduced time to reduced frequency weighting coefficients. The computational complexity for the Doppler channel parameterization of the existing channel estimator in number of complex multiplies is (for the above example with V=1, V_T=3): $JV_TM(PL+(N/2)\log_2(N))=5{,}706{,}288$. This has 163.5 times less complex multiplies than the frequency-domain existing channel estimator and 2.67 times fewer complex multiplies than the time-domain only parameterization of the existing channel estimator with nearly identical performance.

FIG. **7** is a flow chart representation of the method performed by a preferred embodiment of the channel estimation device of **500** to compute the channel gain between at least one transmitting device and at least one receiving antenna in accordance with the present invention. The first step **710** is to initialize the channel estimation device of the present invention based on the choice of time and frequency correlation functions $r_T(n)$ and $r_F(f)$, respectively, a noise correlation matrix, and the pilot sequences of the transmitting devices. The frequency correlation function is a sampled continuous frequency correlation based on the Fourier Transform of a square delay profile in the continuous time-domain, as shown in equation (20). The time correlation function is associated with a flat Doppler spectrum, as shown in equation (21). A set of estimated channel gains is compiled **720** as a function of the pilot sequences, a set of analytical channel gains variables, and a set of weighting coefficients variables. The weighting coefficients $q_j(d)$ are computed as a function of time and frequency correlation functions $r_T(n)$ and $r_F(f)$ a noise correlation matrix, and the pilot sequences of the transmitting devices **725**. The weighting coefficients are collected into a weighting matrix **730** and stored in memory. Initialization of the channel estimation device completes at **740**. Normal operating mode commences **750**, and the receiving device receives data **760** over an information burst **410** and collects the data received during the training symbol interval **420** into a matrix of received training data Y. The device computes the frequency-domain channel gains for each desired transmitter at each antenna by multiplying the matrix of received data Y by the weighting matrix **770**.

FIG. **8** is a flow chart representation of steps performed by the channel estimation device of **500** to provide frequency domain channel estimates between a transmitting device and a receiving antenna utilizing reduced computational complexity in accordance with the present invention. Device initialization is begun **805** when a primary weighting matrix is provided **810**. The primary weighting matrix for desired transmitter j at frequency k and time b are denoted as $E_j(k,b)$. In a preferred embodiment, $E_j(k,b)$ equals $\Psi^{-1}\alpha_j(k,b)$ of Equation (14)), but $E_j(k,b)$ may be provided as an alternative equation from any embodiment using the $\hat{H}_j(k,b)=YE_j(k,b)$ structure. Next, **820** a frequency-interpolation matrix is computed as the minimization of the square of the difference between a set of auxiliary frequency-domain channel gains variables H, and a set of time-domain channel gains variables h, weighted by a set of auxiliary weighting coefficients. In equation form, this minimization is expressed as

$$\min_{h_{j,m}(b)} |H_{j,m}(b) - Gh_{j,m}(b)|^2,$$

where $h_{j,m}(b)$ is the set of time-domain channel gains, $H_{j,m}(b)$ is the set of auxiliary frequency-domain channel gains, and G is the set of auxiliary weighting coefficients who's value is defined by equation (25). The above equation is solved by the frequency-interpolation matrix and is expressed as $(G^HG)^{-1}G^H$. A final weighting matrix is computed as a function of the primary weighting matrix and the transpose of the frequency-interpolation matrix **830** thus completing the device initialization **840**. In equation form, the final weighting matrix $Q_j(b)$ is expressed as $Q_j(b)=A_j(b)G^*(G^TG^*)^{-1}$, where

$$A_j(b)=[E_j(1,b)| \ldots |E_j(K,b)].$$

The normal mode of device operation begins **850** when a matrix of received training data Y, is compiled from the received training sequences **860** at a least one antenna output. Time-domain channel gains are computed **870** as a function of the final weighting matrix and the matrix of received training data and is expressed as $\tilde{h}_j(b)=YQ_j(b)$, where

$$\tilde{h}_j(b)=[h_j(0,b)| \ldots |h_j(L-1,b)]$$

and $h_j(l,b)=[h_{j,1}(l,b), \ldots, h_{j,M}(l,b)]^T$. Finally, the frequency-domain channel transfer gains for each desired transmitter at each antenna output is computed as the DFT of the time-domain channel gains **880**.

FIG. **9** is a flow chart representation of steps performed by the Channel Estimation Device of **500** to provide frequency domain channel estimates between a transmitting device and a receiving antenna utilizing frequency interpolation in accordance with the present invention. Device initialization begins **905** with the computing of a frequency-interpolation matrix. The matrix is computed as the minimization of the square of the difference between a set of auxiliary frequency-domain channel gains variables H, at a set of frequencies, and a set of time-domain channel gains variables h, weighted by a set of auxiliary weighting coefficients **910**. In equation form, this minimization is expressed as

$$\min_{h_{j,m}(b)} |H_{j,m}(b) - Gh_{j,m}(b)|^2,$$

where $h_{j,m}(b)$ is the set of time-domain channel gains, $H_{j,m}(b)$ is the set of auxiliary frequency-domain channel gains at a set of frequencies k_1 through k_K, and G is the set of auxiliary weighting coefficients who's value is defined below. An example set of frequencies is $k_1=1$, $k_2=3, \ldots, k_{256}=511$. One embodiment of the present invention would be provided channel estimates at the above set of frequencies and the present invention would interpolate the provided channel estimates to the even frequencies 2, 4, . . . 512. The frequency-interpolation matrix solves the equation for the weighting coefficient set as $(G^HG)^{-1}G^H$ which ends the device initialization **920**. The structure of $h_{j,m}(b)$,

$$H_{j,m}(b), \text{ and } G \text{ are } h_{j,m}(b) = \begin{bmatrix} h_{j,m}(0,b) \\ \vdots \\ h_{j,m}(L-1,b) \end{bmatrix},$$

DIGITAL GAUSSIAN WHITE NOISE GENERATION SYSTEM AND METHOD OF USE

This invention relates generally to apparatus and methods of generating electrical noise, and more particularly to apparatus and methods of generating Gaussian white noise.

BACKGROUND OF THE INVENTION

In order to test communication and other electronic equipment, noise generators are frequently utilized. The most common type of noise source is an analog device which relies upon a thermal noise diode to generate Gaussian noise.

In particular, commercial noise sources generally depend on the statistics of electron flow across PN junctions to generate noise which has a Gaussian amplitude distribution and a flat frequency spectrum. Generally, the noise power level is known only approximately and it will vary with time and the ambient temperature. The testing of electronic equipment at high bit rates typically requires a wide band noise source. For some testing applications, e.g., to match a lower data rate, the noise can be filtered to reduce its bandwidth. However, this results in a concomitant reduction in the amplitude of the noise, thereby requiring amplification to restore the noise to its original level. Thus, for some testing applications a number of analog noise generators, each providing a different bandwidth, are utilized to cover the desired bit rate range. However, such an approach is not without some drawbacks, e.g., precise amplification of the various generators must be achieved.

The generation of noise via the use of a digital source has been proposed as an alternative to analog noise generation. In this connection pseudorandom binary sequence generators, e.g., shift registers, have been used as noise sources in commercial instruments for some time. Typically, analog noise is generated from the binary output of such registers by severely limiting its bandwidth with an analog low-pass filter. Alternatively, it has been proposed (See Lipson, Foster and Walsh, "A Versatile Pseudorandom Noise Generator," IEEE Trans. Instrumentation and Measurement, Vol. 25, No. 2, June 1976) to use a weighted sum of the binary levels at various points on a shift register to synthesize a digital signal. This approach generates an approximately Gaussian amplitude distribution while also flattening the output frequency spectrum. However, the resultant noise bandwidth is severely limited, e.g., is 1/20 of the clock frequency at which the shift register is shifted.

Another approach to the synthesis of noise via digital techniques is to utilize a digital filter to generate a Gaussian amplitude distribution, but with the same (sine X)/X bandwidth distribution as the input sequence. (See Rowe and Kerr, "A Broad-Spectrum Pseudorandom Gaussian Noise Generator", IEEE Trans. Automatic Control, Vol. AC-15, No. 5, October 1970). Accordingly, this approach does not meet the requirement for flat noise spectrum.

The concept of separating the function of generating a flat frequency response from that of generating a Gaussian amplitude response has been discussed (See, Neuvo and Ku, "Analysis and Digital Realization of A Pseudorandom Gaussian and Impulsive Noise Source", IEEE Trans. on Communications, Vol. COM-23, No. 9, Sept. 1975). However, this approach has not been applied to real-time generation of wide band noise.

Still another approach to digital synthesis of noise ha been proposed. That approach utilizes plural digitally generated noise samples for generating an analog output by means of a digital-to-analog converter. (See Kafadar, "Gaussian WhiteNoise Generation for Digital Signal Synthesis", IEEE Trans. Instrumentation and Measurement, Vol. IM-35, No. 4, Dec. 1986). However, with such an approach, if processing is done in real time the noise bandwidth is limited by the processor speed. If random-stored values are used, the requirement for some values to occur with low probability makes the memory size prohibitive.

OBJECTS OF THE INVENTION

Accordingly, it is the general object of this invention to provide apparatus and a method for digitally generating Gaussian noise which overcomes the disadvantages of the prior art.

It is a further object of this invention to provide apparatus and a method for digitally generating Gaussian noise which is white, that is, which has substantially constant power output per unit frequency interval.

It is a further object of this invention to provide apparatus and a method for digitally generating Gaussian white noise of a wide bandwidth and of substantially constant amplitude.

It is a further object of this invention to provide apparatus and a method for digitally generating Gaussian white noise having an adjustable bandwidth.

It is a further object of this invention to provide apparatus and a method for digitally generating Gaussian white noise of substantially constant amplitude which is relatively simple in construction.

It is a further object of this invention to provide apparatus and a method for digitally generating Gaussian white noise of substantially constant amplitude and wherein the ratio of the peak amplitude of the noise to its rms value meets commercial standards.

It is a further object of this invention to provide apparatus and a method for digitally generating Gaussian white noise of substantially constant amplitude utilizing finite impulse response filters which are binary weighted.

SUMMARY OF THE INVENTION

These and other objects of the instant invention are achieved by providing a method and apparatus for digitally synthesizing substantially Gaussian white noise of an adjustable bandwidth and of substantially constant amplitude.

The apparatus comprises pseudorandom sequence generation means, delay generation means, finite impulse response filter means, and summing means. The pseudorandom sequence generation means has a large plurality of output stages and is arranged for providing first digital electrical signals representing pseudorandom number sequences of a long repetition rate at the output stages. The delay generation means is coupled to selected output stages of the pseudorandom sequence generation means for providing second respective digital electrical signals representing respective uncorrelated pseudorandom number sequences whose spectrum is a predetermined function. The finite impulse response filter means is weighted and coupled to respective ones of the delay generation means for altering the predetermined function spectrum of the pseudorandom number sequence of the second electrical signals to produce respective first analog electrical signals of substantially

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of **Wallén**	
Serial No.: **10/991,878**	PATENT PENDING
Filed: **18 November 2004**	Examiner: Lihong Yu
For: **Method and Apparatus to Compensate for Receiver Frequency Error in Noise Estimation Processing**	Group Art Unit: 2611 Confirmation No.: 8906

Docket No: **1009-0472 / P19605 US2**

Mail Stop Appeal Brief - Patents
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

REQUEST FOR REHEARING

Appellant submits this Request for Rehearing in response to the Decision on Appeal entered by the Patent Trial and Appeal Board on 11 March 2013. No fee is believed to be due in connection with this submission. However, if a fee is deemed due, the Commissioner is authorized to charge such fee to Deposit Account No. 50-5650. This Request for Rehearing is filed within two months of the mailing date of the Decision on Appeal, and is thus timely filed.

As detailed below, the Appellant submits that the Board has overlooked the absence of any record evidence to support the Examiner's findings that the cited reference discloses "generating an initial noise correlation matrix … based on propagation channel estimates," as recited by claims 6 and 29. Reconsideration of the Board's affirmance of the rejections of these claims is thus respectfully requested.

STATUS OF CLAIMS

Claims 1-35 are pending. Claims 1-35 stand rejected by the Examiner in an Office Action dated 31 July 2009 (hereinafter, "the Pending Office Action"). The Decision on Appeal (hereinafter "Decision") by the Patent Trial and Appeal Board (hereinafter "Board") dated 11 March 2013 affirmed the rejection of claims 1-35. Appellant requests that the Board rehear its decision to affirm the rejection of claims 6 and 29.

ARGUMENT

Summary

In adopting the Examiner's findings with respect to claims 6 and 29 as their own, the Board has overlooked that the record includes no evidence to support the Examiner's findings that Russell discloses "generating an initial noise correlation matrix … based on propagation channel estimates." In fact, the record shows that Russell does not disclose the generation of any noise correlation matrix at all, and includes no suggestion or mention of "propagation channel estimates."

While the Board's Decision nominally addresses the rejections of claims 6 and 29, the Decision includes no discussion of the "propagation channel estimates" recited in the claims. Neither does the Examiner's Answer. Accordingly, the only record evidence pertaining to the "propagation channel estimates" of claims 6 and 29 is the Appellant's unrebutted evidence that Russell fails to mention or suggest propagation channel estimates at all. For at least this reason, as detailed below, the rejections of these claims should be reversed.

Discussion

Claims 6 and 29 stand rejected under 35 U.S.C. § 103(a) as allegedly unpatentable over U.S Patent No. 4,477,912 to Russell (hereinafter "Russell"). Claims 6 and 29 depend from independent method claim 1 and independent computer-readable medium claim 25, respectively, and contain similar limitations. Claim 6 is representative:

> *6. The method of claim 1, wherein generating a noise correlation estimate for a received signal comprises generating an initial noise correlation matrix based on a received reference channel signal and corresponding propagation channel estimates.*

Claims 6 and 29 each specify the generation of an initial noise correlation matrix based on, *inter alia*, propagation channel estimates.

The Office Action of 31 July 2009 only briefly addresses claims 6 and 29. Except for quoting the claim language, the Office Action's analysis makes no mention of propagation channel estimates at all. The entirety of the Office Action's analysis is as follows:

> ***Consider claims 6 and 29:***
> *Russell discloses the invention of claims* ***1*** *and 25 above. Russell discloses generating an initial correlation matrix based on a received reference channel signal and corresponding propagation channel estimates* (see Russell at col. 8, lines 59-68, where Russell is discussing correlates incoming pseudo random binary code words with similar locally generated reference pseudo random binary code words).

The Appellant's Appeal Brief of 3 February 2010 requested that the Board review whether dependent claims 6 and 29 were properly rejected, and presented arguments specifically directed to these claims. (Appeal Brief at 17-18.) Those arguments pointed out that Russell does not mention propagation channel estimates at all, and that Russell more generally fails to disclose any of the features of claims 6 and 29. The Appeal Brief's arguments on this point are reproduced below (with emphasis added):

> ***4. The rejections of dependent claims 6 and 29 are without any basis in fact, as Russell does not teach or suggest the generating of an initial noise***

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> ***correlation matrix based on a received reference channel signal and corresponding propagation channel estimates.***
> *The Pending Office Action's rejection of claims 6 and 29 appears to be based entirely on the fact that Russell happens to use the word "reference."* See *Office Action at p. 4; see also Russell at col. 8, lines 59-68. In fact, Russell does not teach or suggest the generation of an initial noise correlation matrix, or any matrix at all. Russell does not make any mention of a reference channel, or a received reference channel signal. And Russell does not make any mention of propagation channel estimates. Because Russell only discloses one word of the claims, but none of the actual features of the claims, the rejections of claims 6 and 29 should be reversed.*

The Examiner's Answer of 30 March 2010 repeats verbatim the rejection of claims 6 and 29 from the Office Action. The Examiner's Answer responds to some of Appellant's arguments regarding these claims, but does not discuss the "propagation channel estimates," and does not rebut the Appellant's contention that Russell fails to disclose this limitation of the claims. The entirety of the Examiner's response to Appellant's arguments with respect to claims 6 and 29 is as follows:

> ***(5) Applicant's Arguments:*** *"In fact, Russell does not teach or suggest the generation of an initial noise correlation matrix, or any matrix at all".*
> ***Examiner's Response:*** *As is seen at col. 8, lines 59-68, Russell is discussing "correlates incoming pseudo random binary code* ***words*** *with similar locally generated reference pseudo random binary code* ***words".*** *As is known by one of ordinary skill in the art, a matrix is just a collection of data items, or an array of data items. Therefore, a plurality of the correlation values is equivalent to a correlation matrix.*

In its Decision on Appeal, the Board adopted the Examiner's findings with respect to claims 6 and 29 as its own:

> *[W]hile Appellant raised additional arguments for patentability of the [claims 2-35], we find that the Examiner has rebutted in the Answer each and every one of those arguments by a preponderance of the evidence. (Ans. 18-20.) Therefore, we adopt the Examiner's findings and underlying reasoning, which are incorporated herein by reference. Consequently, we have found no error in the Examiner's rejections of claims 2-35.*

The Board's Decision thus includes no discussion directed to the specific features of claims 6 and 29.

The Appellant respectfully submits that the Board has overlooked that the record includes no evidence to support the Examiner's finding that Russell discloses "generating an initial correlation matrix based on … propagation channel estimates," as required by claims 6 and 29.

As pointed out in the Appeal Brief, Russell does not disclose the generation of an initial noise correlation matrix based on propagation channel estimates, at least because Russell makes no mention of propagation channel estimates whatsoever. The Examiner's analysis of claims 6 and 29 cites only a short section of Russell in support of its finding. The cited portion of Russell (col. 8, lines 59-68), is as follows:

> *Before describing FIG. 2 in detail, it should be pointed out that the decoding system shown therein correlates incoming pseudorandom binary code words with similar locally generated reference pseudorandom binary code words. However, it should be understood that the decoding system of the invention can be used with any type of digital coding and that pseudorandom coding is not at all necessary. However, for the purpose of simplifying subsequent description, the pseudorandom binary code words as generated by the encoding system of FIG. 1 will assumed as being received at the input to the decoding system of FIG. 2.*

The cited portion of Russell does not relate to generating an initial noise correlation matrix, and does not mention propagation channel estimates. Instead, it simply states that Russell's CDMA detector does not necessarily need to use "pseudorandom" code words, but may use other "digital coding" instead. This discussion has no relation to "propagation channel estimates." No other portion of Russell mentions or even hints at propagation channel estimates, either. Accordingly, Russell does not disclose or suggest the limitations of claims 6 and 29, which require the generating of an initial noise correlation matrix based on propagation channel estimates.

As shown above, the cited portion of Russell fails to disclose or suggest the generating of an initial noise correlation matrix based on propagation channel estimates. The Examiner's Answer does not rebut this, and does not point to any other evidence of record to support its

factual finding that Russell discloses this limitation of claims 6 and 29. For at least this reason, the Examiner's rejections of claims 6 and 29 should be reversed. Reconsideration of the Board's Decision on Appeal is thus respectfully requested.

Conclusion

For the reasons discussed above, the Appellant respectfully requests that the Board reconsider and reverse the rejections of claims 6 and 29 and order the reopening of prosecution in this matter.

Respectfully submitted,

Murphy, Bilak & Homiller, PLLC

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10 May 2013

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CERTIFICATE OF FILING AND SERVICE

I hereby certify that on January 21, 2014, I electronically filed the foregoing with the Clerk of Court using the CM/ECF System, which will send notice of such filing to the following registered CM/ECF users:

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I further certify that, upon acceptance and request from the Court, the required paper copies of the foregoing will be deposited with United Parcel Service for delivery to the Clerk, UNITED STATES COURT OF APPEALS FOR THE FEDERAL CIRCUIT, 717 Madison Place, N.W., Washington, D.C. 20439.

The necessary filing and service were performed in accordance with the instructions given to me by counsel in this case.

/s/ Shelly N. Gannon
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